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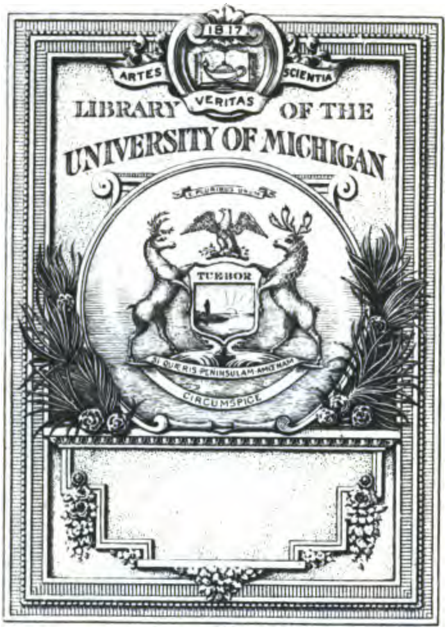

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PHILOSOPHICAL CONVERSATIONS:

OR, A NEW

SYSTEM

OF

PHYSICS,

By Way of DIALOGUE.

With Eighty Nine COPPER PLATES.

Written in French by Father *REGNAULT*
of the SOCIETY of JESUS.

Tranſlated into Engliſh and illuſtrated with NOTES

BY

THOMAS DALE, M. D

In Three VOLUMES.

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TO

Sir HANS SLOANE *Bart*.

Preſident of the COLLEGE of PHYSICIANS, and of the ROYAL SOCIETY.

SIR,

TO be inquiſitive into the Works of God in the Creation, is moſt worthy of a rational and intelligent Being; to employ our Thoughts upon this Subject is to cultivate the higheſt Principles and beſt Inclinations of our Nature. Productions of Art indeed at firſt ſtrike us with Admiration and Delight, but then their Beauty is of no long Duration, and that, which before appeared ſo very lovely and charming, in a ſhort Time becomes greatly unſatiſfactory and diſtaſteful. On the contrary, the Works of Nature are capable of affording us a ſolid and more laſting Entertainment. With what Pleaſure do we ſurvey thoſe numberleſs Orbs rowling over us in the moſt regular and harmonious Order; with what Delight do we trace the Comets (thoſe fiery Bodies that ſtrike ſuch Terror into vulgar Minds) through Worlds unnumbered and unknown? And how does this Pleaſure and Delight riſe upon us, when we imagine thoſe ſeveral Orbs furniſhed with a rich Variety of Inhabitants, as is a very reaſonable Suppoſition, conſidering that not the leaſt Spot of this our Earth is without its Domeſticks? Such Speculations not only afford infinite Satisfaction to inquiſitive Minds, but lead them naturally on to the Contemplation of that greateſt and beſt of Beings, *who knoweth the Number*

ber of the Stars, and who calleth them by their Names.

If we deſcend into our ſelves and take a View of our own Bodies, we ſhall there find the ſeveral Parts adjuſted in ſuch a regular Manner, and ſo exquiſitely well adapted to anſwer all the Ends and Purpoſes of Life, that he muſt certainly be very ſlow of Underſtanding, who is not immediately convinced of his being the Workmanſhip of an infinitely wiſe, good and powerful Artiſt. Farther, ſhould we extend our Views all around us, and run over the ſeveral Species of Animals, Plants and Inſects that inhabit and adorn this our Globe, ſhould we endeavour to trace the Footſteps of divine Wiſdom in the Order, Harmony and Uſes of every one of them, we ſhould ſoon find ourſelves loſt in an endleſs Purſuit, and readily cry out with the *Pſalmiſt*, *Who* *can ſearch out the Almighty or his Works to Perfection!*

In ſhort, the Study of natural Philoſophy fills the Mind with vaſt and ſublime Ideas of the firſt Cauſe and Original of all Things, and is the beſt Means to preſerve it from *Atheiſm* on the one Hand, and *Superſtition* on the other.

But I would not be thought to ſay this to You, Sir, in Commendation of a Study, which has been ſo remarkably encouraged by your Patronage and Example; it is natural to indulge one's Sentiments upon a pleaſing and agreeable Subject.

In the following Work, which I have now the Honour of inſcribing to You, I can claim little more than the Merit of having been, as I hope, a faithful Tranſlator. In the Original our Author has given good Proofs of his Induſtry and Abilities, but then he has at the ſame Time abundantly ſhewn how difficult it is to efface Notions and Impreſſions received in our earlieſt Education. However this is not ſo much to be wondered at, if we reflect how many Men of Learning and Reputation, even amongſt ourſelves, labour under the ſame unhappy Circumſtances. In Order therefore to remedy this Evil, I have taken Care to interſperſe the whole Work with proper Notes, founded upon the Principles laid down by that illuſtrious Ornament of our Nation, the incomparable Sir *Iſaac Newton*.

I SHALL not pretend, Sir, to copy the uſual Forms of Dedications, being thoroughly apprized how difficult a Taſk it would be, even to attempt the Praiſe of a Gentleman, who has deſerved ſo well of the Learned World. Such a Subject would prove ſuperior to much abler Pens.

WHEREFORE as in this Caſe, *Silere præſtat quàm pauca dicere*; I ſhall content my ſelf with the Honour of being eſteemed,

Sir,

Your moſt obliged and

Obedient humble Servant,

THOMAS DALE.

THE

TRANSLATOR's PREFACE

TO THE

READER.

THE many great Improvements that have been of late made in natural Knowledge, have induced a Variety of Perſons to turn their Speculations this Way. That immortal Reputation which Sir Iſaac Newton *acquired by his Writings, has* *ſo far excited the Curioſity of many who are involved in the Hurry of Buſineſs, as to ſet aſide ſome Part of their Time, to inform themſelves of his ſurprizing Diſcoveries. Even the* Belles *forego their darling* Quadrille, *and are proud of being accounted Diſciples of this great Man; and the* Beaus *in Compliance with the Faſhion, are tempted to reſemble rational Creatures in ſomething more than the exterior Form.*

But ſince it requires a greater Knowledge in the Mathematicks than moſt Perſons are bleſſed with to read Sir Iſaac Newton *with any Succeſs, many able Pens have been employed to ſet his Works in a more popular* View; *ſome of whom, I confeſs, have gained much Reputation and Eſteem by their Attempts, and others no leſs private Emolument. Yet ſtill none of theſe Writings were ſufficiently diveſted of Lines and Figures to be generally uſeful and inſtructing; wherefore I have diverted myſelf for ſome Time paſt at my* *vacant Hours in tranſlating the following Work, which I now preſent to the Publick. It is drawn up by Way of Converſation, which Manner of Writing ſeems beſt ſuited to ſet Truth in the eaſieſt Light, and inſenſibly to inſtil Knowledge into the Mind of the Reader. The ingenious Author has run thro' the whole Circle of natural Knowledge, and collected a great Number of curious and entertaining Experiments, many of which are taken from the Memoirs of the* French *Academy; ſo that the* Engliſh *Reader has here an Opportunity of ſeeing the ſeveral Diſcoveries that have been made by the Philoſophers in* France. *But tho' theſe Experiments are agreeably related, yet are the Facts oftentimes but very unluckily accounted for; which is owing to our Author's ſtrong Attachment to the Sentiments of* Des Cartes, *which have been long ſince overturned by the Demonſtrations of Sir* Iſaac Newton; *and tho' our Author, as appears from the following Sheets, was not wholly*

wholly unacquainted with the Writings of that great Man, yet were the Prejudices of Education ſo prevalent as to exclude all Conviction. By this we ſee there may be Bigots in Philoſophy as well as in Religion. However, to remove this Inconvenience, I have ſubjoined the Principles of the Newtonian *Philoſophy by Way of Notes (after the Manner of the late learned Doctor* Clarke *in his Edition of* Rohault) *by which Means the Reader will have the Pleaſure of comparing the Old Philoſophy with the New, and of perceiving the Advantage of the latter, by applying it to the Experiments before him. If this Work ſhould ſucceed, according to my Wiſhes, in the Inſtruction and Entertainment of the Reader, I ſhall think my Pains ſufficiently anſwered; if not, the Goodneſs of my Intention will juſtify the Undertaking.*

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PHILOSOPHICAL CONVERSATIONS BETWEEN *Ariſtus* and *Eudoxus*.

INTRODUCTION.

SINCE the Academies of *Paris*, *London*, *Italy* and *Germany*, and the moſt happy Genius's of *Europe*, at once animated with the Love of Truth, the Commendations, Favour and Beneficence of Princes, have united their Endeavours to diſcloſe the Secrets of Nature, Philoſophy has its Charms and its Graces: It pleaſes, is univerſally admired, beloved, and every where favourably received, even at the Court it ſelf.

Eudoxus has been particularly delighted with this Study from the Time he was firſt capable of reliſhing it. Since that Time no Employment was ſo pleaſing to him, as to admire the Strokes of divine Wiſdom manifeſted in the Structure and Beauty of the Univerſe, and ſtudy thoſe ſecret Receſſes which diſplay ſo many Wonders to our Eyes.

The Light which diſcovered to him the Heaven and the Earth, the Sight of a Fountain, a Flower or an Inſect was capable of entertaining and delighting him all the Day long. A Sky brilliant with Stars made the Night appear to him as beautiful as the Day. Should Darkneſs or thick Clouds veil the Sun from his Eyes; ſhould the Rain ſucceed to a ſerene Sky, a Tempeſt to a Calm; his Enquiries into, and Apprehenſions of the different Cauſes which produce theſe Viciſſitudes and various Effects, ever afforded him a new Pleaſure. In the Height of Winter amidſt his philoſophick Meditations, even the Rigour of the Seaſon preſented to his curious Mind ſuch ſurprizing Changes, as made him forget the Flowers of the Spring, and the Fruits of Autumn, and made him ſome Amends for the abſent Pleaſures of the moſt ſmiling Seaſons. He could not conceive how a Man could deny himſelf the Pleaſure of employing his leiſure Time in contemplating the Hand of the Creator, even in the ſmalleſt of all viſible Beings. The Sight of Truth infuſed into his philoſophick Soul Pleaſures perhaps as piquant, at leaſt more pure, as well as more ſolid, than thoſe which are taſted at the moſt agreeable Feaſts in the World. Thus the Joy which overflowed his Heart, ſeemed to diffuſe itſelf over his whole exterior Form. His Air was affable, and his Manner engaging. There was nothing auſtere in his Philoſophy: It was natural, equally grave and Pleaſant, and procured him the Eſteem, the Confidence, and Friendſhip of *Ariſtus*.

In the Perſon of *Ariſtus*, were united all the Graces of the Mind, together with thoſe of the Body. He was a young Man, who was entirely free from the Vices of Youth. He was born a Philoſopher, an Enemy to that ſoft Idleneſs in which ſo many Youths languiſh, who are wholly taken up with unreaſonable Pleaſures, vain Amuſements, Comedies and Operas, bounding their Knowledge, at moſt, with being able to write a Madrigal or a Song, in catching the Airs of ſome *Petit-Maître*, or the Pleaſures of the Bottle. Nature, Birth and Education had inſpired the Soul of *Ariſtus* with Sentiments far more noble; he ſaw nothing more worthy of Man, than the Knowledge of himſelf, and every Thing that ſurrounded him. In the Flower of his Age, and in the Seaſon of Pleaſures, he had a more ardent Paſſion for the Diſcovery of the Source and ſecret Cauſes of Things, than he had for Pleaſure itſelf. The Eſteem which he found the Philoſophers of the Academy enjoyed among all Sorts of Perſons, whoſe good Opinion was of any Value, raiſed a noble Emulation in him. He was pleaſed to ſee Philoſophy talk a Language ſo harmonious and delightful in their Works. But he wanted ſome Perſon verſed in the reading of theſe Works, and already initiated into the Myſteries of Nature, to ſecond his Taſte, and facilitate his underſtanding the moſt agreeable Truths. He was charmed to find this Perſon in *Eudoxus*. The ſame Taſte, the ſame Inclination, ſoon united them very ſtrongly together, and in a Chain of continued Converſations, and which ſeem to ariſe one out of the other; they agreeably unravelled every Thing which we find the moſt curious and delightful in the Univerſe.

CONVERSATION I.

Eud. WELL, *Ariſtus*, your Taſte then inclines you to Natural Philoſophy? I like it ſo much the better, becauſe I am indebted to this Inclination for the Eſteem, Confidence and Friendſhip wherewith you are pleaſed to Honour me. I ſhall endeavour to ſecond it. I am heartily at your Service, and ſhould find Pleaſure in being capable of procuring you any.

Ariſt. Nothing is more generous, than to find one's Pleaſure in procuring it to others. Upon this Account I hope you will receive ſome Satisfaction in illuminating me with your Light; for I freely confeſs, that I feel an eager Deſire of knowing my ſelf, and what ſurrounds me and affects my Senſes; and I would without any Difficulty ſacrifice all the vain Pleaſures which the World can preſent me with, to the Pleaſure I take, or imagine, in this Knowledge.

Eud. The Pleaſure which accompanies this Knowledge, is alone in my Judgment worth all the others put together. Even from *Cicero*'s Time Phyſicks have been looked upon as the moſt pleaſant, delicious and agreeable Food of the Mind. What Allurements then muſt they not have at this Time, ſince they have been enriched with an infinite Number of new Diſcoveries? By the Light of this Science the Mind at once obſerves that Wiſdom, which by certain ſimple but fertile Laws of Motion, preſcribed and freely followed by itſelf, draws out of Matter this Variety, Aſſortment and admirable Arrangement of terreſtrial, tranſparent, and luminous Bodies; it penetrates into the Boſom of the Earth, there it perceives after what Manner Nature forms Diamonds, Silver and Gold for enriching us; there it diſcovers the Origin of Winds and ſubterraneous Fires; it ſees theſe Fires kindled, and the Winds formed, ſhaking the Earth, and ſpreading abroad a ſalutary Horror. It perceives that Force which makes the Waters aſcend by a thouſand Channels, even to the top of the Mountains, to form there thoſe Springs ſo fit for refreſhing us; it knows after what Manner the Earth being warmed covers itſelf with Flowers in the Spring, and ſends forth Vapours, Exhalations and Clouds into the Air, and in thoſe Clouds the Thunder and the Thunder-bolt; by what Courſe the Rays that come from the Sun proceed to be broken and reflected in the Clouds, ſo as to preſent us with the moſt beautiful Colours. From the midſt of the Air it aſcends to the Planets. What do I ſay? It bounds from one Vortex to another, even to the Extremities of the World; and from the remoteſt Stars, it returns again to conſider with a freſh Pleaſure, the rapid Circulation which carries Blood and Life into all the Parts of a human Body.

Ariſt. This lively Deſcription would doubtleſs be ſufficient to engage one for ever to Phyſicks.

Eud. Phyſicks have a thouſand and thouſand other Charms ſtill more capable of affecting and raviſhing an attentive Mind. But ſince in order to follow both your Taſte and mine, we purpoſe to run over the Whole, without dwelling but upon that Part which is moſt curious and profitable; let us endeavour to do it with ſome Order, ſo that our Converſations may ſeem to ariſe from one another, and the firſt may afford ſome Light into the ſubſequent. Perceptions which ariſe from one another, are both the eaſier, and more conſpicuous.

Ariſt. Pray, let us begin with a clear and exact Idea of Phyſicks. When any one ſpeaks, I love to know what he is diſcourſing upon.

Eud. Philoſophy is properly the Knowledge of Bodies. Its Character is to diſcover to us the general Principles, Properties, and Arrangement of Bodies; the Nature and Properties of every Species of Bodies; in a Word, the Effects, and the Cauſes of thoſe ſenſible Effects, whence that Harmony and Beauty reſult which our Senſes admire in this vaſt Univerſe.

Ariſt. This Idea ſeems clear, diſtinct and beautiful. But what Principles do you ſuppoſe to reign equally in all Bodies?

Eud. Matter and Form.

Ariſt. Do you believe that Matter is ſufficiently known by the Information of our Senſes?

Eud. I know that the divine Power can and does ſuſpend upon our Altars * the Impenetrability of Matter, or that which is the Cauſe why a Portion of Matter, which I call a Part or Particle, when compared with another that is greater, admits no other into it. In ſhort, Matter is a Subſtance naturally impenetrable; this is univerſally allowed, and this is ſufficient for comprehending and explaining thoſe Wonders which affect us; is not this a ſufficient Knowledge of Matter?

Ariſt. If Matter were not naturally impenetrable, we ſhould quickly, I imagine, ſee thoſe Wonders which affect us, diſappear to the Eye; in an Inſtant the Earth, Stars, and Heavens would approach and penetrate one another, and by penetrating, ſtraiten one another ſtrangely; and we ſhould be greatly aſtoniſhed to find our ſelves almoſt annihilated, and to ſee the whole Univerſe reunited in one Point: Or rather that Univerſe has never had any Exiſtence. But is it very certain that Matter is naturally extended, and that every Part has Length, Breadth and Thickneſs?

Eud. Two Particles, however minute, being united together, form an Extenſion; for if two do not, why ſhould three or four? But

---

* Our Author, I ſuppoſe, alludes here to the Doctrine of Tranſubſtantiation.

Things which have no Extenſion, make none by their Union. Do they touch one another? They perfectly penetrate one another, the one admits the other into it; the one has nothing without the other, ſeeing they touch one another in all imaginable Points; otherwiſe each of them would contain Particles ſtill more minute, the one without the other, and thence would be extended without being ſo in Reality; but Reaſon acknowledges no ſuch Contradictions in Nature. What follows from this? That every Part of Matter is extended. Therefore Matter is extended in its natural State. Geometry ſupports this Reaſoning, and no one has yet demonſtrated its Defect.

Ariſt. Therefore the ſmalleſt Parcel that one can imagine, muſt contain in it Parts more minute, even *ad infinitum*. How much every Thing that ſeems to approach Infinity makes us ſenſible that our Underſtanding is limited! The Mind loſes itſelf in a ſurprizing Multitude of ſmall Beings; it finds therein no more Hold. Thoſe Nothings, if I may ſo call them, ought to confound the Pride of Philoſophers, if they had as much as ſome aſcribe to them.

Eud. The Imagination is loſt here, rather than the Mind; for if you divide a Particle into the moſt inconceivably minute Parts, the Mind will always find therein ſomething that regards the Weſt, and ſomething that regards the Eaſt; and what regards the Weſt, is not that which regards the Eaſt.

After all, whether the Mind find in Matter Particles aſſignable and diviſible *in infinitum*, or not, this Enquiry ſo famous from the firſt Riſe of Philoſophy, and which has only tormented the fineſt Wits in vain, can be of little other Uſe than to keep Philoſophers modeſt; an Endeavour vain enough. In order to reliſh the Pleaſure of underſtanding what is ſurprizing in thoſe Effects, whoſe Marvellouſneſs depends upon the Smallneſs of the imperceptible Parts, it is ſufficient to know that every ſenſible Part of Matter contains Particles imperceptible, and ſmaller the one than the other, far beyond our Imagination. This is what every one knows whenever he pleaſes, and what may be learned from very curious Experiments.

For Garments that are perfumed with Roſes preſerve a pleaſant Scent a long Time; a ſmall Grain of Incenſe is perceivable through the whole Extent of a large Hall. A Grain of Muſk, formed like a ſort of Salt in the Bladder, of a kind of Roebuck, without loſing hardly any Thing of its Subſtance, exhales for whole Years a very ſtrong Odour, capable of enfeebling Serpents of an enormous Bigneſs at a certain Diſtance, ſtopping, lulling aſleep, and rendering them immoveable [a]. Now, how can this happen, if odoriferous Bodies do not contain almoſt an infinite Number of Corpuſcles of an incredible Smallneſs, which are divided, diffuſed every Way, and ſtrike the Organ of Smelling? A ſmall Plate, a very minute Piece of Braſs diſſolved in Spirit of Sal Armoniac, affords a ſufficient Number of imperceptible Particles to colour a Quantity of Water two hundred Times greater. Let a Drop of this coloured Water fall upon a lighted Lamp, it will be divided ſo prodigiouſly by the Heat, that for the Space of half an Hour the Flame will appear wholly blew. One Grain only of Vitriol diſſolved in 9216 Grains of common Water, ſenſibly dyes all this Quantity with its Colour [b]. But you will perhaps have more Pleaſure in conſidering the enormous Multitude and Smallneſs of the Parts of Matter in Gold; the ſole Idea of this precious Metal has ſomething in it of the Flatterer.

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[a] Recueil XIV. des Lettres édifiantes des miſſionaires de la C. de J. p. 493.

Ariſt. Can one be affected with the Splendor of Gold, *Eudoxus*, when the Secrets of Matter are unveiled to the Eye, and one has a Taſte for Truth? I would venture to lay any Sum of Gold imaginable, that a Philoſopher, like you, would find more Pleaſure in knowing it well, than in poſſeſſing it.

Eud. A Philoſopher, like me, lays hold on Things as they come; he poſſeſſes without Covetouſneſs, but yet he poſſeſſes, being leſs affected with his Poſſeſſion, than with an Enquiry of M. *Rohault*'s. This Gentleman [c] by

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[b] Mem. de l'Acad. 1706. p. 413.

[c] 1. Par. c. 9.

Calculation found in a cubical Foot of Gold, 21584 Ounces, in every Ounce more than four Millions of Lines; in every Line, how many Points or more minute Particles might the Mind ſtill ſee? Have you never ſeen them draw Gold in *St. Dennis's-ſtreet?*

Ariſt. I have, and was aſtoniſhed. The Drawers have a Silver Cylinder of about fifteen Lines in Diameter, and 22 Inches long, covered ſometimes with about ſix Ounces, ſometimes with about one Ounce of Leaf of Gold, inſeparably attached to the Silver, by Virtue of the Heat, and the rubbing of the Blood-Stone. At firſt they make one End of the Cylinder or Ingot, enter into the biggeſt Hole of the Wire-drawer, which is a Plate of Steel pierced through with a Number of Holes. Then they lay hold on it with Gags faſtened to a Cable drawn by a Capſtane, which is turned round by five or ſix Men: The Cylinder paſſes through, and is lengthened in paſſing; then they run it ſucceſſively through an hundred and a hundred Holes, proportionably ſmaller the one than the other; and at laſt paſſing through Holes almoſt imperceptible, the gilded Ingot or Cylinder becomes a Thread of Gold, which is properly nothing but a Silver Thread gilded, which is afterwards wrought upon Silk, to ſupport the Luxury of rich Attire, and cheriſh the Vanity of thoſe who deck themſelves with Threads of Gold, without obſerving what thoſe Threads have in them more worthy to engage the Attention.

Eud. According to the Calculation of *M. de Reaumur*, a celebrated Member of the Academy [d], an Ingot of Silver of 45 Marks, and which was only 22 Inches long, gained 1396240 by being drawn into Wire; imagine then what a Number of imperceptible Parts there muſt be in ſo ſmall an Extent!

Ariſt. Here I equally admire Nature and Art; Nature in the wonderful Ductility of Silver and Gold, and Art in the wonderful Effects which it thence draws, and which we take no Notice of, becauſe they are continually under our Eyes.

Eud. This is yet nothing. This ſingle Ounce of Leaf-Gold laid upon the Silver Cylinder, is drawn out into Gold Thread by the Wire-drawer, and is lengthened enough upon the Silver to equal the Length of 100 Leagues, and unite *Lyons* to *Paris* by a ſort of Golden Chain. It is likewiſe poſſible by Art to lengthen it out to 120 Leagues of 2000 Fathoms each.

Ariſt. But what then is the Thickneſs of the Gold in Places where the Thread is leaſt gilt?

Eud. Perhaps one Million and the fifty thouſandth Part of a Line. When the Buſineſs is only to divide a Piece of Gold of one

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[d] Mem. de l'Acad. p. 201.

Line into a Million different Leaves, it is but a Trifle.

Ariſt. What ſurprizing Smallneſs of Particles!

Eud. What ſurprizing Smallneſs, ſay you? Nay I tell you that thoſe ſmall Beings, whoſe Smallneſs aſtoniſhes you, are immenſe, and even Coloſſes when compared with Millions of other Beings. The Smallneſs of a Mite, which perhaps is the leaſt of ſenſible Animals, is but little inferior to that of the Particles of Gold; and *M. de Malezieu*, ſaw with a Microſcope, living Animals 27 Millions of Times ſmaller than a Mite [e]. Through their tranſparent Skin he perceived Bowels, Eggs, the Forms of their *Fœtus* or young ones, and a ſort of Blood circulating by contrary Motions. Theſe Animals, 27 Millions of Times leſs than the leaſt perceptible ones, muſt then have in their almoſt infinite Smallneſs, Eyes, Feet, Inteſtines, Veins, Arteries, an Heart, and Blood. The fineſt Particles of their Blood are probably to their Bodies, as the fineſt Particles of our Blood, called animal Spirits, are to ours. The fineſt Particles of our Blood, are almoſt infinitely ſmaller than our Bodies; therefore the fineſt Particles in thoſe animated Beings are almoſt infinitely ſmaller than their Bodies, which are 27 Millions of Times leſs than a Mite. Well, *Ariſtus*, would your philoſophical Imagination deſire, for its Satisfaction, Particles yet more minute, and penetrate ſtill farther into the imperceptible Principles of Matter?

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[e] Hiſt. de l'Acad. 1718. p. 19.

Ariſt. I own it, my Imagination loſes itſelf here in the enormous Smallneſs of thoſe Particles; but it loſes itſelf, I believe, without going aſtray: For the Moment it is loſt, through want of finding an Hold, it encourages my wavering Mind, and emboldens it to acknowledge in Matter, Particles ſtill more delicate, even to Infinity.

Every Thing conſpires to perſuade me, that Matter is a Subſtance naturally impenetrable and extended. Can any one not agree to it? But Matter, which in its natural State preſents nothing to the Mind but Length, Breadth, and Thickneſs, has nothing of itſelf to rank it under one Species of Body rather than another: What then is this ſecond Principle of inanimate Bodies, this Form, which of a Portion of Matter makes one Species of Body rather than another; Gold rather than Silver, a Diamond rather than Cryſtal, a Pink rather than a Tulip, and a Tube-roſe rather than a Roſe?

Eud. It is the Configuration, the Arrangement, and the Texture of thoſe Parts, whoſe Smallneſs eſcapes your Imagination, and ſeems, as it were, to be loſt in Non-entity. For imagine only in ſeveral Portions of Matter divers Configurations, Arrangements, and Textures of the imperceptible Parts, and you will conceive ſeveral Species of Bodies; for Example, Marble, Agate, or Pearl. Do not we ſee Bodies paſs from one Species to another; without any other Change than a new Texture of the imperceptible Parts? The Agitation of Fire produces nothing elſe in Salt and Sand when melted together; and yet theſe two Bodies thus melted, conſtitute Glaſs proper for defending us from the Injury of the Air, without denying us the Uſe of Light. The Juices of the Earth are not Plants of themſelves; but ſhould they be ranged differently, they become different Plants; theſe Juices being agitated by the natural Heat, inſinuate themſelves into divers Buds; and according to the various Structure of the Fibres and ſmall Cells they meet with therein, they are turned, modified, placed, and ranged after a Thouſand Manners. Thus of Juices, nay often of the very ſame Juices, are formed the Violet, the Anemone, the Ranunculus, and that charming Variety of Flowers, with which our Meadows and Gardens are enamelled in the Spring. Now, ſince the different Texture of imperceptible Particles conſtitutes different Bodies, it is likewiſe ſufficient for the Form of thoſe Bodies; Why then ſhould it be ſought for elſewhere?

Ariſt. I love to ſee you introduce Flowers into your Diſcourſe, *Eudoxus*; it makes your philoſophical Sentiments appear the more delightful. Your Flowers pleaſe me, but yet I am more affected with your Reaſons. To them

I yield with Pleaſure, and it is indeed impoſſible to refuſe one's Aſſent.

Eud. What then in general, according to your Opinion, are thoſe different Bodies, whoſe Aſpect cheers our Senſes?

Ariſt. They are ſo many Portions of Matter, whoſe imperceptible Parts have their proper Configuration, Texture and Arrangement.

Eud. I think we have ſufficiently dived into the Nature of Bodies in general. To Morrow we will ſee if there are any Bodies in the Univerſe.

CONVERSATION II.

Concerning the Exiſtence of Bodies, and the Air in particular.

Ariſt. CAN one demand ſeriouſly, *Eudoxus*, whether there be any ſuch Things as Bodies exiſting? The ſole Pleaſure of ſeeing you, ſpeaking to you, and hearing your Voice, cannot in the leaſt permit me to doubt it. They tell us indeed [f] that certain *Indians* acknowledge only Spirits; but thoſe *Indians* are Infidels, who are deluded by the Spirit of Darkneſs. Could ever any one be found in *Europe*, out of a Madhouſe, who acknowledged nothing in this vaſt Univerſe but Phantoms of Bodies?

Eud. When we are not upon our Guard againſt new Notions, we eaſily ſuffer our ſelves to be impoſed upon. We form to our ſelves new Principles; and hence the moſt ridiculous Conſequences procure our Aſſent without Contradiction. The moſt whimſical Imaginations become familiar to us; our Vanity finds a Satisfaction in thinking after an unuſual Manner.

[f] Dans les Lettres édifiantes des Miſſionaires de la C. de J.

This Snare hath drawn more than one modern Philoſopher into the Folly of the *Indians*. The Abbot *** makes no Myſtery of it, he acknowledges in himſelf only one half of himſelf; and notwithſtanding the Weight of his Body, which ſeems to revenge this Affront by the Pains it cauſes to the Soul, without deliberating he looks upon himſelf as a pure Spirit, which without a Body receives according to I know not what imaginary Laws of Nature, the Impreſſions which it would receive if there were Bodies, and if he had one himſelf,

Ariſt. Probably that he may act in a ſuitable Manner, and carry on his new Philoſophy to the utmoſt, he neither eats nor drinks.

Eud. Oh! herein you are much miſtaken, he eats and drinks better than any Body. The Wines of *Tonnerre* or *Champagne*, and Pheaſants or Ortolans, have nothing in them too material for this pure Spirit. He loves Concerts, Shows, Comedies and Operas. You may oftner ſee him in Circles of corporeal Beauties, than at the Foot of the Altar, contemplating the Beauty of the pureſt of Spirits. He never denies himſelf the honeſt and lawful Pleaſures of Senſe; yet when he taſtes them in Reality, he thinks he only enjoys them in Idea. Sometimes we take Deluſion for Reality; he takes Reality for Deluſion, but loſes nothing by it, except the Reputation of a wiſe Man, by Virtue of his being a Philoſopher.

Ariſt. He has loſt more in my Judgment; he has loſt the Truth. For, in ſhort, the Scripture which contains the holieſt Maxims, the nobleſt Ideas of the Deity, and a Worſhip moſt worthy of God; the Scripture, which cannot deceive us, teaches us that there are Heavens, Earth, Plants, Waters, Seas, Men who ought to feed upon the Subſtance of a God-Man, an Air which Men breathe, a Moon, a Sun, and Stars; all Beings created by the Hand of the Almighty. Can theſe created Beings be only ideal Beings? Can they only exiſt in my Mind, or in the Ideas of God, that is to ſay, be created without being created?

Eud. Do you believe that without the Aſſiſtance of Faith one can rightly know the Exiſtence of thoſe Beings?

Ariſt. I am convinced of it: We know it without the Aſſiſtance of Faith, if the conſtant Information of our Senſes, an unavoidable Biaſs engraven on our Souls by the Author of Nature, the Idea of God and Reaſon, all concur to teach it us. In an important Affair, where the Queſtion is about knowing whether we owe any external Worſhip to God or not, we ought to depend upon ſuch like united Rules of judging. Now all this conſpires at once to make us ſenſible of the Exiſtence of Bodies; for 1. at all Times, conſtantly, and from my Birth, I perceive by my Senſes a Thouſand and a Thouſand different Bodies; and in this Variety I can diſtinguiſh the ſame

Bodies. 2. I find in my ſelf a neceſſary Inclination to believe what the conſtant Information of my different Senſes tell me concerning the Exiſtence of Bodies: This Inclination has nothing in it foreign to my Nature, I received it with my Life; therefore muſt have received it from the Author of Nature. 3. The Author of Nature is equally good and wiſe; of this the Idea of God convinces me. Being equally good and wiſe, would he permit me to deceive my ſelf in judging both upon the conſtant Information of my Senſes, and upon a neceſſary and natural Inclination which he has planted in my Soul, and alſo upon the Idea which I have of his Wiſdom and Goodneſs, in a Matter of Conſequence, wherein I do nothing contrary to Reaſon, but am rather authorized by it? My Reaſon tells me that God does not permit it, at leaſt without derogating by a Miracle from the Laws of his ordinary Providence, one of which unavoidably leads me to judge that there are Bodies.

Therefore without the Aid of Revelation I know the Exiſtence of Bodies.

Eud. But you who doubt ſo little of the Exiſtence of Bodies, are you well aſſured that your own is not a Phantom?

Ariſt. If my Body is only a Phantom, I owe no external Worſhip to God: But I owe him an external Worſhip; every Thing tells me ſo, my Reaſon cannot doubt it; therefore my Body is no Phantom. Seeing I am a reaſonable Being, I ought to be capable of diſcerning whether I owe my Creator an external Worſhip or not; but I cannot diſcern it without knowing whether I have a Body, or not. All the ſoundeſt Rules of Truth oblige me not to queſtion whether I have a Body; therefore, *&c.*

Eud. Your Reaſonings are ſolid.

Ariſt. They ought to be ſo; I have drawn them from your Writings.

Eud. You are too forward in praiſing, *Ariſtus.* A true Taſte of Truth rarely praiſes.

Ariſt. A true Reliſh of Truth pays to Merit the Tribute that is due to it, and Praiſe is the natural Tribute of Merit.

Eud. There needs no extraordinary Merit to find out Reaſons for judging that there are ſenſible Bodies before our Eyes. But is there a Species of imperceptible Body more refined than the Air itſelf, and which after *M. Deſcartes*, we may call ſubtle Matter, and celeſtial Matter? Nothing is of greater Importance to Phyſicks; it is perhaps the moſt fertile Source of the Wonders of Nature. In order to diſcover this fertile Source, we muſt firſt have ſome Idea of this Air which we breathe.

Ariſt. The Air, *Eudoxus*, which we breathe, preſerves and prolongs our Days; is it not very juſt then that we beſtow ſome Moments upon enquiring into its Properties?

Eud. It certainly has ſurprizing Properties; and what appears to me yet more aſtoniſhing is, that the greateſt Part of Mankind are ſenſible of their Efficacy, without knowing them. Hardly do the Vulgar know there is ſuch a Thing as Air, unleſs the Reality of it be manifeſted to their Senſes by the Guglings of a Bottle, cauſed evidently by the interrupted flowing of the Liquor, and the violent and alternate entering of the Air.

They call Air this tranſparent Liquid which ſurrounds us immediately, which the Face or Hand feels when one agitates it rapidly with the Hand only, or with a Fan, and which carries Coolneſs and Life into the Lungs by Reſpiration. This Liquid encompaſſes the whole Earth, ſince it is equally a Principle of Life for all Men every where. It is extended even above the Top of the higheſt Mountains; and its univerſal Extenſion is what we call the Atmoſphere †.

The Atmoſphere, tho' its Tranſparency renders its ſmall Parts inviſible, is blue in itſelf; for 1. Lift up your Eyes towards Heaven in fair Weather, and it preſents this Colour to your View on all Sides, which makes us give the Name of Sky-blue to that which reſembles it moſt. 2. You would ſay that a Sky-blue were ſpread over the high Mountains, which one ſees at a Diſtance through the Atmoſphere. 3. In the Night, when the Air is without a Cloud, receive upon a Sheet of white Paper, but ſeparated in two Places by an opake and perpendicular Piece of Paſtboard, the Light of the Moon, and of a Candle; the Place enlightened by the Light of the Candle appears reddiſh; and that by the Light of the Moon appears blue [g]. Is not this becauſe the firſt has paſſed through a little Air, and the other by paſſing through much, the Colour of which is blue, is in ſome ſort dyed with it? It is true, the Air which is near us does not appear blue, but that is becauſe in a ſmall Space there are not Parts enough coloured in ſuch Sort, as to make any ſenſible Impreſſion. Thus while a Glaſs of Wine appears to be of a lively red, and ſuch as invites us to drink, one Drop only of the ſame Wine has but a weak Colour; becauſe in the full Glaſs there is a Number of Parts livelily coloured, the Impreſſion of which is united in the Eye, while there are only a few in the Part that is ſeparated; and if the Wine contained in the Glaſs is but faintly coloured, the ſeparated Drop appears as clear as Water.

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† See Notes on Converſation XXII and XXIII.

Ariſt. What then is the Nature of this coloured Air?

Eud. The Air is a Body whoſe Parts are very fine, ſhort, agitated, leſs indeed than thoſe of Fire, but more than thoſe of Water, ramoſe, flexible, having a Stiffneſs and a Springineſs like thoſe of Cotton. 1. The Air is a Body; for it makes itſelf to be felt, it cools, and has

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[g] Mariote, de la Nature de l'Air, p. 227.

Extenſion. Faſten a burning Coal to the Bottom of a Veſſel turned upſide down perpendicularly; plunge the Veſſel into Water; the Coal is ſunk without being extinguiſhed; but for what Reaſon? Becauſe the Air having no Vent, and preſenting to the Surface of the Water the equal and ſmooth Surface of its own Extenſion, with the ſame Reſiſtance in all the Parts of its Surface, hinders the Water from penetrating, and approaching the Coal. 2. The Air has Parts very fine and ſhort; it flows through imperceptible Pores, is moved, gives Place, and is divided, without any ſenſible Reſiſtance, in our paſſing from one Place to another. 3. The Air has Parts agitated; it dries Linnen: How is that done? Why by looſening the ſmall Parts of the Liquor, which it cannot do but by the Agitation of its own Parts. 4. The Parts of the Air are leſs agitated than thoſe of Fire, becauſe the Fire dries Linnen much quicker. But the Particles of the Air are both more agitated and more minute than thoſe of Water; accordingly the Air conveys Odours more effectually, neither does it freeze, while Water is turned into Ice. Finally, the Parts of the Air, though they are very fine, are nevertheleſs branchy, flexible, and elaſtic, ſince the Air is compreſſed and dilated like Cotton.

Ariſt. Has the Air, ſay you, its Spring?

Eud. A Body which is contracted and bent by the Action of ſome foreign Force, and which is dilated and unbent as of it ſelf, has its Spring or elaſtic Virtue: Now the Air is contracted and dilated, bent and unbent, after this Manner: For 1. preſs an ordinary Foot-ball on all Sides: It is compreſſed, and cannot be ſo without the Contraction and bending of the internal Air. Forbear that Preſſure, and the Foot-ball will be extended: Why? Becauſe the internal Air being ſet at Liberty, it is dilated and unbent. 2. By Means of a ſmall compreſſing Pump and ſome Suckers, they make the Air enter at ſeveral Times into the Cavity or Chamber of a ſort of Fuſee, which they call a Wind-gun. The Suckers being ſhut up by the Effort which the Air makes to get out, retain it there on one Hand; a moveable and cylindrical Key retains it on the other; and there you may compreſs, bend and contract it twenty, fifty, nay a hundred Times more, if you will, than it was contracted without. Run a Bullet into the Barrel of this philoſophical Fuſee, and turn the Key: The Air being freed, ſuddenly iſſues out, and violently drives the Bullet before it: Take Care not to ſtand before the Mouth of the Fuſee, for being pierced with the Stroke, you would take the Effect of the Air for that of Gunpowder, though too late. The Bullet will pierce a Plank through and through. Let us try the Experiment. Whence Proceeds this ſurprizing Effect, if not from the ſucceſſive Contraction and Dilatation of the Air? Therefore the Air has its Spring. Further, I ſay it has Weight. One Day or other we ſhall ſee a Proof of this in its marvellous Effects. Let us return to the ſubtile Matter; or rather let us defer it till to Morrow.

CONVERSATION III.

Upon the Exiſtence of the ſubtile Matter.

Ariſt. I Do not well know, *Eudoxus*, how you will convince me that there is ſubtile Matter in the World. I have ſeen ſome old Philoſophers, nay Profeſſors of Philoſophy, who are equally to be reſpected both for their Age and Dignity, declaim vehemently againſt this ſubtile Matter. If you ſhould hear them in their Tranſports, it is nothing but the Effect of an Imagination capable of overturning both Phyſicks and Morality. They produce a a Reaſon for it which you would not eaſily conjecture; that is, that they cannot ſee this ſubtile Matter.

Eud. The Reaſon is wonderful! They are of ſuch an Age, that they can ſcarcely ſee the biggeſt Objects at their Feet; and yet in a gay humour they annihilate the ſmalleſt, becauſe they do not ſee it. I am much afraid, leſt thoſe antient Enemies to a ſubtile Matter, far from annihilating it, ſhould become annihilated themſelves in our Eyes, through the want of a ſubtile Matter to warm that Blood which old Age has froze in their Veins.

Ariſt. But pray, *Eudoxus*, what do you underſtand by ſubtile Matter? Is it that globulous Matter, thoſe imperceptible hard and round Bodies, whoſe Diſcovery and Original are equally aſcribed to *M. Deſcartes*? Or that Matter which is ſtill more minute and more agitated, which according to the Fancy of our modern Philoſophers, changes its Figure more eaſily than *Proteus*?

Eud. I underſtand here in general by ſubtile Matter ‡, a Matter finer than the Air which we breath; Matter very minute, and which being continually agitated after a Thouſand and a Thouſand different Ways, and preſerved in its Agitation by that of the Stars and the Sun, cannot fail of taking and having in its Corpuſcles, a Thouſand and a Thouſand different Figures, triangular, ſquare, ſpherical, *&c.*

Ariſt, But how do you prove the Exiſtence of a Matter, which you ſeem to believe as antient as the World itſelf, and which yet appears new to many of the Learned.

Eud. To prove this, I obſerve, and ſhall make others obſerve, a Fact in a Machine, which they ſometimes call *Boyle*'s Machine, ſometimes an Air-Pump, or *Machina Vacui.*

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‡ See the Notes upon Converſation V.

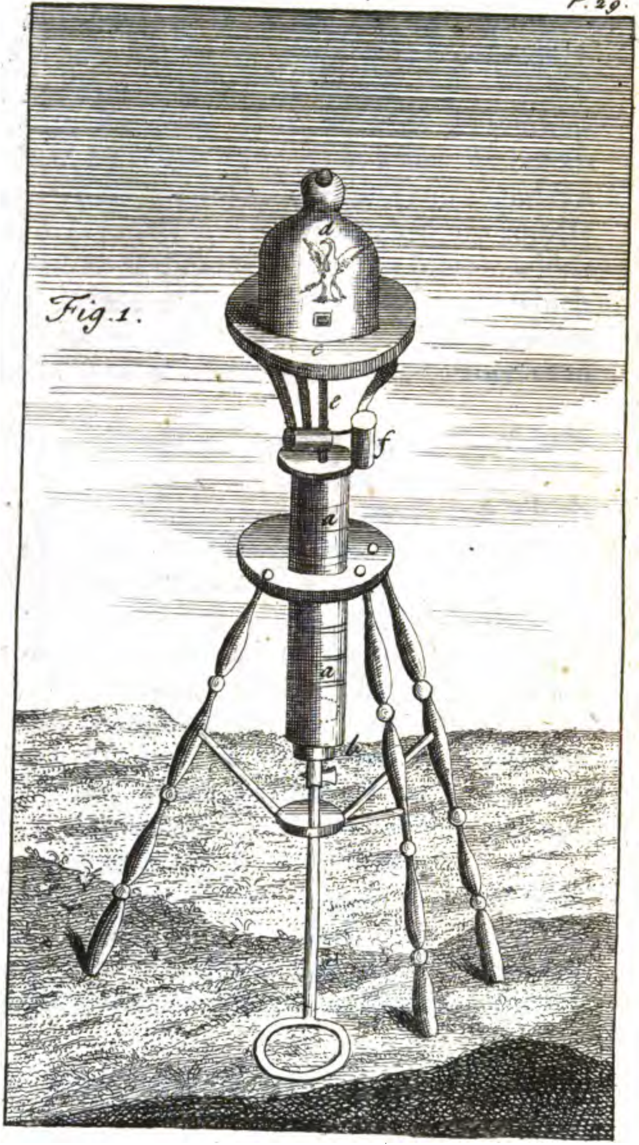

Fig. 1.

Pray obſerve mine, *Fig.* 1. It is compoſed, as you ſee, of a Pump, or hollow Cylinder *(a)*; a Piſton, or ſolid Cylinder *(b)*, which aſcends or deſcends at Pleaſure; a Copper-Plate *(c)*, bored through the Middle, upon which I place a Veſſel of Cryſtal *(d)*, made almoſt in Form of a Bell, and which is called the Receiver; a Pipe *(e)*, which communicates with the Barrel and the Receiver by the Hole in the Plate; a cylindrical and moveable Key *(f)*, which divides at right Angles like the Screw of a Cock, and ſhuts or opens at Pleaſure the Communication of the Barrel and Receiver. The Key, when it ſhuts the Communication, has in its inferior Surface a Groove, or ſort of ſmall Channel, by which the Air may iſſue out of the Barrel without entering into the Receiver.

If I open the Communication, and draw the Piſton downward, you will hear the whizzing of a liquid Matter, which paſſes with an accelerated Swiftneſs from a larger Space into a narrower, from the Receiver into the Barrel, by the Hole of the Plate. I raiſe the Piſton, after having ſhut the Hole of Communication; the pumped Matter iſſues out impetuouſly by the Grooves of the Key: I continue pumping at ſeveral Times. The liquid Matter ſtill iſſues out with a Noiſe, aſſiſting my Endeavour to draw the Piſton; but at laſt the Noiſe ceaſes, and my Effort is no longer ſeconded.

Pump an hundred Times without ſuffering the pumped Matter to enter again into the Receiver: The Receiver never fails to be full of Matter; for it is full of Light, and Light is a Body, ſince a Light too lively hurts the Eyes, and it is only one Body that diſorders, touches and hurts another: Now this Matter which always fills the Receiver, is different from that which is pumped out. That which is pumped out, cools, and preſerves Life. Animals die in the other; this Goldfinch, in which I take ſo much Pleaſure, would preſently loſe therein both its Gaiety and Life, as an hundred little Sparrows have already done. The firſt whiſtles in going out; and my Watch ſtrikes in it what Hour you pleaſe; the other makes no Noiſe, and the Watch is never heard in it. The firſt ſeconds the Deſcent of the Piſton, the other does not in the leaſt facilitate it: The firſt neither penetrates Glaſs, nor Cryſtal; for otherwiſe being driven out of the Pump by the Groove, it would return in making a Circuit, paſs through the Receiver, enter into it again, and always produce the ſame Effect; as Air driven out of a Chimney by the Flame, always returns with the ſame Whiſtling through the Cracks of the Doors or Windows: The other penetrates the Receiver without Reſiſtance, ſince it ſucceeds the former, and tranſmits Light to our Eyes. The firſt then muſt be more groſs, and that is Air; this other muſt be finer, and is the ſubtile Matter. Therefore there is ſubtile Matter, which was the Thing to be proved.

There is, I ſay, a ſubtile Matter, and this ſubtile Matter is as old as the Univerſe, if there is in the Air, which we breath, Matter finer than Air itſelf: Now there is in the Air Matter finer than the Air itſelf; for Matter which penetrates Glaſs and Cryſtal, is finer Matter than Air itſelf; the Air which carries Life into our Lungs neither penetrates Glaſs nor Cryſtal, ſince Animals die for want of Air in a large Veſſel of Glaſs or Cryſtal: But there is in the Air a Matter which penetrates Glaſs and Cryſtal; Light certainly penetrates both the one and the other, ſince it makes us ſee coloured Objects through both; and its Rays paſſing through a Priſm preſent to our Eyes the Colours of the Rainbow, and paint a Wall with the moſt beautiful Colours: Now Light is Matter diffuſed in the Air, it is a Body; in ſhort, Light touches, agitates and hurts the Eyes; and what touches, agitates, and wounds a Body, is Body: *Lucretius* ſpeaks like a Philoſopher, when he ſays:

Tangere enim & tangi, niſi corpus, nulla poteſt res.

Body alone can touch, and touches only Body: Therefore there is a ſubtile Matter.

But further, is there not a Matter more delicate than Air, a ſubtile Matter, which in Time of Heats being ſenſible, if I may thus ſpeak, of the new Degrees of Heat, pierces the Glaſs of the Thermometer, and therein makes the Spirit of Wine ferment and aſcend, in order to let us ſee with the Eye thoſe new Degrees of Heat which we feel? And muſt not ſome Matter of this Species inſinuate itſelf into the Boſom of the Earth by a Thouſand imperceptible Channels, in order to give by their Motion to divers Elements that Configuration, Arrangement and Texture, which conſtitute precious Stones, Silver and Gold? Is it not a ſubtile Matter, which directs, agitates and animates the Loadſtone, and iſſues out of its Subſtance, in order to encompaſs it with a Vortex of Filings of Iron; and makes Iron or Steel court it or fly from it, while precious Stones, Gold or Silver make no Impreſſion thereon? Is it not this ſame Matter which by imperceptible Paſſages ſearches out, corrodes, undermines, and conſumes the internal Parts of hard Bodies, and reduces to Duſt, Stones and the moſt ſtately Edifices? Is it not that which by its Agitation cauſes the Fermentations, the Fluidity of the Blood and Humours, and renders the Subſtance of the Brain more ſoft, flexible, and fit for producing new Ideas.

Ariſt. That is to ſay, ſubtile Matter works Miracles in the Sight of thoſe who admire them, while they do not acknowledge it. It enlightens them, yet they perceive it not; its Light diſcovers the moſt ſecret Myſteries, and yet does not make itſelf known; it remains in

Darkneſs, while it ſpreads a Light over all; it gives Vivacity and Penetration to the Mind, yet the Mind uſes them maliciouſly againſt it: For you may daily hear ſome of your new Philoſophers jeſting upon ſubtile Matter. It is the Source of Riches, and yet is rejected; it revives old Age, which would gladly reduce it to nothing, or diſſipate it, if by its prodigious Subtlety it did not eſcape the Eyes of its Enemies. (By making Men happy, it makes them ungrateful).

Eud. I apprehend, *Ariſtus*, that the very Idea of a ſubtile Matter awakens your good Humour. Perhaps the ſubtile Matter has a greater Share therein than you think of; the lively, but moderate Agitation, which it produces in your Blood and the Fibres of your Brain, ſerves to diſſipate any cloudy Humours, and give you pleaſing Ideas. You jeſt, you laugh at my Sentiments concerning a ſubtile Matter; I hope our Converſations will convince you of its Reality, and that this ſubtile Matter has made you a Man of Wit, without making you an Ingrate.

Ariſt. I believe your Sentiment in the Main is ſolid, *Eudoxus*; I am for a ſubtile Matter. It cheers my Mind; I love to ſee it circulate at your Pleaſure through the whole Univerſe, and work Wonders every where. Nay its Smallneſs gives me no Uneaſineſs neither, ſince we have ſeen Animals ſeven and twenty Millions of Times leſs than a Mite. But how came

Ariſtotle, whom they call the Genius of Nature, not in the leaſt to perceive this fertile Source of Wonders?

Eud. Though *Ariſtotle* did not perceive it, it was however not at all the leſs real: H[illegible] had no Notion of the Circulation of the Blood, which flowed in his Veins; yet the Blood has never ceaſed to circulate in all Men from the very firſt even down to us, paſſing with a prodigious Rapidity from the Heart to the Extremities of the Body, and returning with the ſame Velocity from the Extremities to the Heart, as we ſhall ſee one Day or other. But read *Ariſtotle*; you underſtand the *Greek*, tho' unknown to many of *Ariſtotle*'s Enemies; in a hundred Places he ſpeaks of an etherial Matter, of a Fire univerſally diffuſed, in the Air, and above the Air. This Fire, this etherial Matter, is it not the ſubtile Matter, of which they will have *M. Deſcartes* to have been the firſt Inventor?

Ariſt. Though a ſubtile Matter had not obtained the united Suffrages of *Ariſtotle* and *Deſcartes*, yet ſhould I voluntarily yield to your Reaſoning: Notwithſtanding your Reaſons ſuppoſe Bodies to have Pores, that they are pierc'd through with a Thouſand and Thouſand Holes; I ſhould be glad to ſee thoſe Pores, thoſe imperceptible Holes, as clearly as I perceive the ſubtile Matter, and then I ſhould be ſatisfied. I have ſeen ſome Perſons who have been incredulous about theſe imperceptible Pores.

Eud. Well, we ſhall endeavour to ſatisfie you upon this Head in our next Converſation.

CONVERSATION IV.

Upon the Poroſity of Bodies.

Ariſt. WHEN one ſees the whole Univerſe overflowed with a ſubtile Matter, and is convinced that it is, as it were, the Soul of it, we muſt of Neceſſity allow it a free Paſſage in an extreme Poroſity, in order to its ſpreading its Influence univerſally. I dare ſay, *Eudoxus*, that you ſee clearly, even in this ſubtile Matter every Particle, as it were, bored and pierced in a hundred Million of Places at leaſt. But to ſpeak freely, is it probable that all Bodies have their Pores?

Eud. It is not in the leaſt probable that all imperceptible Bodies have them; neither my Eyes nor my Reaſon ſee them in the ſubtile Matter. The Particles of ſuch like Corpuſcles have ſo little Conſiſtence, and are ſo minute, that the leaſt Force ought, I imagine, to unite them immediately. But as the Particles of all ſenſible Bodies have more Solidity, and different Figures, as round, ſquare, *&c.* it is probable that they have Interſtices or Pores. What ſay I, probable? It is a certain Fact, which Reaſon and Experience jointly teach us.

Bodies cannot be compreſſed without Pores; Compreſſion is occaſioned only by the Approach of the Particles, and their Approach ſuppoſes that they were ſeparated by Interſtices, which are otherwiſe called Pores. Experience ſufficiently ſhews that all ſenſible Bodies are compreſſed, even the moſt ſolid. Ivory does it remarkably. Let fall a Billiard Ball from a certain Height upon a Plane of Marble covered over with a light Lay of Tallow; you will ſee in the Tallow a round Figure, pretty large, which could not have been made but by a conſiderable flattening of the Ball. Therefore all ſenſible Bodies have their Pores. Why does Water weigh fourteen Times leſs than an equal ſenſible Portion of Quickſilver? Becauſe Water poſſeſſes no more than the fourteenth Part of the Space which it ſeems to do; ſo many Interſtices are there in it.

What Species of Body is there, that has them not? 'Tis evident that Cryſtals, Rubies, and Diamonds have them; ſince they are tranſparent, and afford a Thouſand free Paſſages to the Light, which is a Body that often dazzles and hurts the Eyes. Why does a Ball of Glaſs, hollow and full of Light, move as eaſily upon an horizontal Plane, as if it contained no other Matter than its own? Becauſe the luminous Matter, of which it is full, iſſues out freely, and other Matter of the ſame Sort enters with the ſame Freedom through the Pores of the Glaſs; otherwiſe the Sphere would make as great a Reſiſtance as if it were full of Mercury, ſince its Reſiſtance would be according to the Quantity of Matter which it contained. Is not your Body all over full of Pores? There is not one Part, wherein Sweat does not find ſome Paſſage in a Criſis, or an exceſſive Heat: And why does it grow lean through your intenſe ſtudying of Philoſophy? Becauſe its Subſtance, which the natural Heat puts into a continual Agitation, is exhaled by Tranſpiration, without your taking any Care to recruit it. Some Philoſophers who have been ſo curious as to weigh both their own Bodies, and the Nouriſhment which they took, and the Superfluity that paſſed off without being changed into Juice, have diſcovered that the greateſt Part of our Aliment muſt be diſſipated by Ways imperceptible.

Ariſt. The Light, which comes to my Eyes through Glaſſes and precious Stones, diſcovers Pores to me therein; that Tranſpiration, which according to you dries me up, obliges me to acknowledge them in my ſelf, beyond what I am able to imagine. But hard and opake Bodies, Oak for Example, Metals which are the moſt compact Bodies, Iron, Silver and Gold, ſhould they be alſo made by Nature to give Acceſs to the ſubtile Matter?

Eud. The ſubtile Matter, which ſince the Origin of the World has been preſerved only by Agitation, ought, no doubt, in labouring to form thoſe Bodies, to have provided therein free Paſſages for neceſſary Occaſions. Would you believe it, *Ariſtus*? Oak has at leaſt twenty Times more Pores, and void Spaces in it, than it has of its own Matter. In ſhort, the apparent Bulk, the Maſs of Oak weighs twenty Times leſs than an equal Bulk of Gold. For Water weighs nineteen Times leſs than Gold; and Oak weighs leſs than Water, ſince it floats upon it. Metals diſſolved by Heat, let us ſee ſufficiently that they have Pores open, and always ready to receive Corpuſcles of Fire, their Deſtroyers and Enemies; but you muſt have Facts more ſurpriſing; then obſerve them.

1. Lime and Orpiment digeſted ten or eleven Hours in Water, over a Sand Heat, afford a clear Liquor. Write with Vinegar impregnated with Salt of Lead, and the Writing does not appear; but the former Liquor paſſing through an entire Book, you will be able to read that inviſible Writing. And this is ſympathetick Ink [||].

2. Shut up in Boxes of any Sort of Metal you pleaſe, ſome Tin or Silver: The ſulphureous Exhalation [h] of the *Boulogne* Stone, newly calcined, finds Acceſs to it, it dyes the Tin with

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[||] Lemery, p. 390.

[h] Mem. de l'Acad. p. 142. 1709.

the Colour of Silver, and Silver with that of Gold. How does the Exhalation paſs through?

M. Hombergh, an expert Chymiſt of the Academy of Sciences, made Salts paſs calmly through Iron and Silver before your Eyes. One may believe it[1]. A Salt extracted from a Mixture of quick Lime, diſtilled Vinegar, Saltpeter, Sea Salt, and common Sulphur, melts in an Iron crucible over a ſtrong Fire, and quietly penetrates the Iron, as Water paſſes through brown Paper, without diſordering any Part, or leaving any Trace of its Paſſage. One Part of Lime drawn from a Solution of fine Silver, two Parts of corroſive Sublimate, and three of crude Antimony, reduced to Powder, mixed exactly, and diſtilled over a Sand Heat, afford a bituminous metalline Matter, which melts like Wax; and being melted upon a Plate of Silver about half a Line thick, is imbibed into this precious Metal, and penetrates it through and through without cauſing the leaſt Alteration in it. Wherefore Nature, which is more wonderful ſtill in what ſhe conceals from our Senſes, than in ſenſible Objects, muſt have diſpoſed in Iron and Silver a prodigious Number of Pores, all communicating with one another. Gold has its own Pores, as well as Silver; for Spirit of Sea Salt diſſolves Gold, and *Aqua Regia*, compoſed of Spirit of Salt and Spirit of Nitre, reduces Gold into a Liquor.

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[1] Mem. de l'Acad. 1713. p. 308.

Without the Interſtices in the Gold, could this Diſſolvent find Acceſs into the Texture of this Metal, or could it eat into it?

Ariſt. The Experiments and Labours of the Academy have certainly given us a great Light into ſeveral very obſcure Things. Your Reaſonings, and the Experiments of *M. Hombergh*, diſcover to me by what Ways the ſubtile Matter can, in ſome Sort, animate the Earth. Thoſe ſecret Ways, thoſe imperceptible Routs, have probably different Figures, and are of various Bigneſs in divers Bodies; the various Texture, which makes different Bodies, ought to cauſe this Variety in the Pores: But I ſhould be glad to have ſome Experiments capable of convincing me beyond all Contradiction. Experiments which ſtrike the Senſes, often confirm our ſtaggering Reaſon.

Eud. Experience in this Caſe ſtill agrees with Reaſon. Why is Spirit of Nitre a proper Diſſolvent of Silver and not of Gold, and Spirit of Sea Salt the proper Diſſolvent of Gold, and not of Silver? Why does *Aqua Regia*, compounded of Spirit of Salt, and Spirit of Nitre, reduce Gold into a Liquor, without diſſolving Silver; while *Aqua Fortis*, in which Spirit of Nitre is predominant, reduces Silver into a Liquor, without diſſolving Gold? The different Poroſity of Gold and Silver probably occaſion thoſe different Effects. Since Gold weighs much more than Silver, probably the Pores of Gold are much ſtraiter. Whence the Points of Spirit of Salt being probably finer than thoſe of Spirit of Nitre, find themſelves too much at Liberty in the Pores of Silver, and make no Impreſſion upon it; but ſliding with ſome Difficulty, notwithſtanding their Smallneſs, into thoſe of Gold, they produce therein the Effect of a Wedge, by dividing and diſſipating the ſolid Parts. On the contrary, the Points of Spirit of Nitre being probably thicker than thoſe of Sea Salt, penetrate into the Pores of Silver with Difficulty, and therein do the Buſineſs of a Wedge, by ſeparating and diſſipating the ſolid Parts: But not being able to run into thoſe of Gold, they make no Impreſſion upon it; however being mixed with Spirit of Sea Salt in the *Aqua Regia*, they find Acceſs into the Gold, corrode and demoliſh it, becauſe the Spirit of Salt makes them fine enough to gain with ſome Effort a Paſſage into the Interſtices of the Gold. Thus Water, which paſſes freely between the Arches of a Bridge, does it no Harm; but ſhould it meet with any Obſtacles, it overturns all. It ſometimes happens that *Aqua Fortis*, too pure, and too ſubtile, is a Sort of *Aqua Regia*, that diſſipates Gold and ſpares Silver: Pour upon it a certain Quantity of common Water, and it will diſſipate Silver, and ſpare Gold. Whence then does this proceed, but from the Inequality of the Pores[k]?

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[k] Hiſt. de l'Acad p. 374.

Wine and Water diſcover to us, as well as Spirit of Salt and of Nitre, a Difference in the Pores; For Wine, which is filtred and inſinuated into the Subſtance of ſeveral Bodies, does not always paſs through where Water paſſes. If you ſuſpect any Mixture of Water in Wine, pour the Liquor into a Veſſel made of Ivy; that Water which might have deceived you under the Appearance of Wine, parts from it, goes off, and diſtills Drop by Drop; the Wine remains at the Bottom of the Veſſel, and the Taſte finds nothing there but pure Wine.

Ariſt. Well, I ſee plainly, you will not have the Water, which takes or ſeems to take the Colour of Wine, take alſo its Nature. You chuſe rather to conceal it in the Pores or Interſtices of the Wine.

Eud. If 'tis poſſible to ſeparate Water from Wine ten Days after they have been mixed, it is evident that Water does not aſſume the Nature of Wine in the Mixture: But this may be done, and Father *Maignan* of the Order of *Minims* has done it*.
" I mixed, ſays he, with one Part of very
" clear Well-water, two Pints of old Wine,
" pure and of a ſtrong red Colour. I let the
" Mixture alone for about ten Days and ten
" Nights in a Veſſel, very little concave, and
" whoſe Mouth was large, waiting for a De-
" gree of cold, fit to freeze the Water without

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* T. I. p. 332.

“freezing the Wine. A North-Wind produced this Effect in the Night. In the Morning I found the Water frozen upon the Window without. I bowed down the Veſſel. The Water remained ſtill immoveable, but immediately almoſt the Wine diſtilled. You might have ſeen the Drops of this Liquor filter through the Water, paſs ſucceſſively from Interſtices to Interſtices, and run into the Veſſel which I had ſet under it. All the Wine quitted the Pores of the frozen Water. It became wholly whitiſh, and was pierced through with Thouſands of ſmall Holes, like a ſort of Fringe. Finally, when the Ice was melted, there was nothing to be ſeen in the Veſſel, but very clean Water, without any Appearance of Wine.

Ariſt. I am equally convinced of the Poroſity of Bodies, and of the Variety of their Interſtices; but fear leaſt my reſtleſs Imagination ſhould ſeduce my Reaſon, when my Eyes do not diſcern the Objects; pray let us try to diſcover the Pores with a Microſcope. Whatever ſtrikes the Eyes, makes a deeper Impreſſion upon the Mind, than any Thing related to us by the Learned: *Horace* very well obſerves †.

> *Segniùs irritant animos demiſſa per aurem,*
> *Quam quæ ſunt oculis ſubjecta fidelibus. —*

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† Ars Poet. v. 180.

End.

Eud. Here is my Microſcope, you may ſee Pores, in ſome Sort, inviſible. You will ſee ſome at leaſt in a Coal; there they are diſpoſed in Order, and very numerous. A certain Philoſopher [1] ſays, that he has ſeen them with a Microſcope, and counted to the Number of 150 in one Row, the eighteenth Part of an Inch long; now according to the Calculation of that Author, a Coal of an Inch Diameter ought to have in it more than five Millions. Obſerve then theſe Pores, and ſhew them to your incredulous Philoſophers, if their Eyes are yet in a Condition to behold Objects magnified, and ſuch as are twenty or thirty Millions of Times bigger than in their natural State.

Ariſt. I am ſenſible there are Pores, *Eudoxus*; but are thoſe Pores empty or not? I ſee nothing in them but Darkneſs; for my Part I can diſcern no ſubtile Matter.

Eud. To Morrow I will tell you my Sentiments on this Head; in the mean Time conſider of it your ſelf; we will endeavour to diſcern if there be really any Vacuum in Nature, or if it be any other than that, which according to the Language of the Vulgar, is often found in the Bottle, the Purſe, or the Head.

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[1] *M. Hook.* Journal des ſçavans, XXII. *Dec.* 1666. p. 738.

CONVERSATION V.

Concerning a Vacuum.

Eud. WELL, *Ariſtus*, ſince our laſt Converſation has your Mind taken any Flight in your profound Meditations upon a *Vacuum?* Has it penetrated this *Vacuum*, this immenſe Nothing, which they place immediately upon the Surface of the World? Has it run over thoſe Spaces where the Sight is loſt, and where Imagination alone wanders at Pleaſure?

Ariſt. My Mind, *Eudoxus*, has made no uſeleſs Journey into your imaginary Spaces; it never went out of this World, which however ought to have its proper Bounds, though the divine Power has none; it remained within my Cloſet, employed about thoſe Pores, thoſe Species of ſmall Vacuities with which Bodies are beſtrewed. And ſeeing nothing there with the Microſcope, no not ſo much as the leaſt Trace of a ſubtile Matter, it aſked itſelf what is a *Vacuum?* Is it poſſible? Does it exiſt? And I think I have hit upon the Truth.

Eud. Your Mind is methodical in its Enquiries; but what is a *Vacuum?*

Ariſt. A *Vacuum* is properly a Surface capable of containing a Body, without containing however any one at all.

Eud. This is the Idea I have of a *Vacuum*. But is a *Vacuum* poſſible?

Ariſt. Can Reaſon doubt it, *Eudoxus*? What ever implies no Contradiction is poſſible; a *Vacuum* implies no Contradiction; for what Contradiction is there in a Surface proper for containing a Body, and which yet contains none at all? Theſe Terms no Way deſtroy one another: Therefore a *Vacuum* is poſſible.

In a Word, ſhould God at once annihilate this Air, and all the Matter wherewith we are ſurrounded in this Cloſet, without making any Change in the Situation of the Cloſet, or in the Bodies that ſurround it, there would be a *Vacuum*, and one might ſay that then we ſhould find our ſelves immediately under Nothing: Now this Suppoſition has nothing in it impoſſible, nothing contradictory, nothing that is above the Power of a God, who ſtands in Need of nothing, who freely preſerves the Bodies which he does preſerve, who can annihilate ſome, without others, ſince they are ſo many diſtinct Subſtances, that he can work a Change in them, or not; therefore, *&c.*

Eud. Neither *M. Deſcartes*, nor *M. Robault*, nor *M. Regis*, two of the moſt celebrated *Carteſians*, were of your Opinion.

Ariſt. I know it, but I know alſo that in this Matter their Underſtanding was the Dupe of their Imagination; their Imagination made them ſee Extenſion in all the intermediate Spaces of Bodies, and this Extenſion they took for a real Extenſion, for a Portion of Matter; but they took the Phantom for the Reality. Let us carry our Imagination as far as we pleaſe beyond 6000 Years, or thereabouts, which are paſt ſince the Creation of the World, our Imagination ſtill ſuppoſes an Extenſion; but in that Extenſion is there any Solidity? None at all; otherwiſe the World would be eternal. Our Imagination feeds itſelf with corporeal Images; the Sight of Bodies fills it with the Image of Extenſion. Hence wherever our Imagination is carried, the Image of Extenſion accompanies it; but this is only an imaginary Extenſion, which has nothing of Body in it, and which vaniſhes before the Eyes of Reaſon.

Eud. Thus far I agree with you in your Sentiments about a *Vacuum*. But is there any *Vacuum* in the Univerſe? I believe there is no ſuch Thing; why? Becauſe there is no Proof of its Exiſtence, and I ſee nothing more uſeleſs than a *Vacuum* for producing the Wonders of Nature.

Ariſt. For my Part, I own freely that ſince I have ſeen with your Microſcope Pores in a prodigious Number, and ſo many Sorts of *Vacuums*, I find it difficult not to acknowledge at leaſt ſome ſmall real *Vacuums* with *Gaſſendus*, *Lucretius*, and *Epicurus*.

Eud. You are then ſomething of an *Epicurean?*

Ariſt. Yes, but then it is only in a Point, wherein one may be ſo with Honour. If I place my fleeting Happineſs in Pleaſure; it is only in the Pleaſure of learning the Truth from your Mouth. I am alſo ſurprized that you are not ſomething of an *Epicurean* your ſelf: For, in a Word, thoſe Pores ſo numerous and almoſt infinitely ſmall, which you have made me ſee in ſenſible Bodies, have a great Appearance of being perfectly void; they are ſo in the Judgment of the Eyes; are they not ſo in the Judgment of Reaſon? What is it that fills them?

Eud. The ſubtile Matter ‡.

Ariſt.

“ ‡ *Since the Reſiſtance of a* fluid Medium *ariſes chiefly from its Denſity, it from thence neceſſarily follows, that where there is no ſenſible Reſiſtanse of the* Medium, *there the* Medium *muſt have no ſenſible Denſity; and therefore ſince in the Heavens the Comets ſuffer no ſenſible Reſiſtance, but exert their Motions with the greateſt Freedom, as if they were in a perfect Void, or* Vacuum, *there likewiſe the Denſity of the* Medium *muſt be the leaſt that can be, or next to nothing. And who knows but the* Medium *in the Heavens may be ſo rare and fine, that if you except the Planets and their Atmoſpheres, the Matter which is diffuſed through all the reſt of the Planetary Region, or our ſolar Syſtem, may not be ſo much as that which is contained in an Inch of our common Air. And this is demonſtrated to be poſſible in* Keil's *Phyſical Lectures.* Keil's Phyſ. p. 202.

“ Liquors which differ not much in Denſity, as Water, Spirit of Wine, Spirit of Turpentine, hot Oil differ not much in Reſiſtance. Water is thirteen or fourteen Times lighter than Quickſilver, and by Conſequence thirteen or fourteen Times rarer; and its Reſiſtance is leſs than that of Quickſilver in the ſame Proportion, or thereabouts, as I have found by Experiments made with Pendulums. The open Air in which we

“ breathe

Ariſt. The ſubtile Matter! But the ſmall Particles of ſubtile Matter have different Figures, round, ſquare, &c. How are thoſe different

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“ breathe is eight or nine hundred Times lighter than Water, and by Conſequence eight or nine hundred Times rarer, and accordingly its Reſiſtance is leſs than that of Water in the ſame Proportion, or thereabouts, as I have alſo found by Experiments made with Pendulums. And in thinner Air the Reſiſtance is ſtill leſs, and at length by rarifying the Air, becomes inſenſible. For ſmall Feathers falling in the open Air meet with great Reſiſtance, but in a tall Glaſs well emptied of Air, they fall as faſt as Lead or Gold, as I have ſeen tried ſeveral Times. Whence the Reſiſtance ſeems ſtill to decreaſe in Proportion to the Denſity of the Fluid. For I do not find by any Experiments, that Bodies moving in Quickſilver, Water or Air, meet with any other ſenſible Reſiſtance, than what ariſes from the Denſity and Tenacity of thoſe ſenſible Fluids, as they would do if the Pores of thoſe Fluids, and all other Spaces, were filled with a denſe and ſubtile Fluid. Now if the Reſiſtance in a Veſſel well emptied of Air, was but an hundred Times leſs than in the open Air, it would be about a Million of Times leſs than in Quickſilver. But it ſeems to be much leſs in ſuch a Veſſel, and ſtill much leſs in the Heavens, at the Height of three or four hundred Miles from the Earth, or above. For Mr. *Boyle* has ſhewed that Air may be rarified above ten Thouſand Times in Veſſels of Glaſs, and the Heavens are much emptier of Air than any *Vacuum* we can make below. For ſince the Air is compreſſed by the Weight of the incumbent Atmoſphere, and the Denſity of Air is proportional to the Force compreſſing it, it follows by Computation, that at the Height of about ſeven *Engliſh* Miles from the Earth, the Air is four Times rarer than at the Surface of the Earth; and at the Height of 14 Miles, it is ſixteen Times rarer than at the Surface of the Earth, and at the Height of 21, 28, or 35 Miles, it is reſpectively 64, 256, or 1024 Times rarer, or thereabouts; and at the Height of 70, 146, 210 Miles, it is about 1000000, 1000000000000, or 1000000000000000000 Times rarer, and ſo on.

“ Heat promotes Fluidity very much by diminiſhing the Tenacity of Bodies. It makes many Bodies fluid which are not ferent Figures matched ſo with the Figures of the Pores, that there does not remain in them the leaſt *Vacuum*?

Eud. The ſubtile Matter being of an inconceivable Smallneſs, is extremely brittle, it is broken and bruiſed; it puts off and aſſumes all

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" fluid in Cold, and increaſes the Fluidity of tenacious Liquids, " as of Oil, Balſam and Honey, and thereby decreaſes their Re- " ſiſtance. But it decreaſes not the Reſiſtance of Water conſide- " rably, as it would do, if any conſiderable Part of the Reſiſtance " of Water aroſe from the Attrition or Tenacity of its Parts. " And therefore the Reſiſtance ariſes principally and almoſt " entirely from the *Vis inertiæ* of its Matter; and by Conſe- " quence, if the Heavens were as denſe as Water, they would " not have much leſs Reſiſtance than Water; if as denſe as Quick- " ſilver, they would not have much leſs Reſiſtance than Quick- " ſilver; if abſolutely denſe, or full of Matter, without any *Va-* " *cuum*, let the Matter be never ſo ſubtile and fluid, they would " have a greater Reſiſtance than Quickſilver. A ſolid Globe in " ſuch a *Medium* would loſe above half its Motion in moving " three Times the Length of its Diameter; and a Globe not ſo- " lid (ſuch as are the Planets) would be retarded ſooner. And " therefore to make Way for the regular and laſting Motions of " the Planets and Comets, it's neceſſary to empty the Heavens " of all Matter, except perhaps ſome very thin Vapours, Steams or " Effluvia, ariſing from the Atmoſpheres of the Earth, Planets and " Comets, and from ſuch an exceedingly rare ætherial *Medium* as " is deſcribed in p. 323. *Newt. Opt.* A denſe Fluid can be of " no Uſe for explaining the Phænomena of Nature, the Motions of " the Comets and Planets being better explained without it. It " ſerves only to diſturb and retard the Motions of thoſe great " Bodies, and make the Frame of Nature languiſh: And in the " Pores of Bodies, it ſerves only to ſtop the vibrating Motions of " their Parts, wherein their Heat and Activity conſiſts. And as it " is of no Uſe, and hinders the Operations of Nature, and makes " her languiſh, ſo there is no Evidence for its Exiſtence, and " therefore it ought to be rejected. And if it be rejected, the " Hypotheſes that Light conſiſts in Preſſion or Motion propa- " gated through ſuch a *Medium*, are rejected with it". *Newton's Opticks*, *p.* 341. &c.

Manner of Figures with an incredible Facility; and ſince Water takes immediately the Figure of a Veſſel, round or ſquare, you ought not to be ſurprized that the ſubtile Matter, whoſe Particles are infinitely more minute than thoſe of Water, ſhould accommodate itſelf perfectly to the Figure of the Pores, and exactly cloſe up all thoſe ſmall *Vacuums* which you are ſo much afraid of ſeeing filled up.

Ariſt. There is a Neceſſity, *Eudoxus*, at what Rate ſoever, that you agree with me concerning thoſe ſmall *Vacuums*, or I will force you to acknowledge much greater ones in Nature.

Eud. By what Means will you force me to that?

Ariſt. By the Rarefaction and Condenſation of Bodies. For how does Bread ſwell? How is Milk inflated ſo ſtrangely when it comes to boil, unleſs its Particles are ſeparated, removed from one another, and leave Interſtices and *Vacuums*, much greater than thoſe, which in Spite of me, you endeavour to fill up with your ſubtile Matter?

Eud. Rarefaction is an Action by which a Body augments its Bulk, without augmenting its Maſs, or which makes the ſame Body preciſely that appeared under a certain Bulk, to appear under a greater: But is it not ſufficient for that, that the ſubtile Matter, or ſome fine Air, fill up, extend and enlarge the Pores, as *M. Deſcartes* believed after *Ariſtotle*? Bread which is baked, ſwells, and is inflated; Milk which boils, is extended, aſcends, and fills the Veſſel; becauſe the little Corpuſcles of Fire, whoſe Agitation produces Heat, penetrate the Bread and Milk, inſinuate themſelves ſucceſſively into their Pores, fill them up, and dilate them ſo much the more, as the Air which they meet with in them is extremely dilated; and thus your great Vacuities are filled up.

Ariſt. For to fill them, you dilate the Air ſtrangely; but upon what Principle?

Eud. This is what Experience proves unanſwerably, that Heat often gives the Air 200 Times more Extenſion than it had in its natural State.

Ariſt. If the Air is extended ſo prodigiouſly, it has then Vacuities, not ſmall, but very large?

Eud. In Proportion as the Extremities of the Air are removed from one another in Rarefaction, the ſubtile Matter, the ætherial Matter, the æther, the celeſtial Matter, (give it what Name you pleaſe) fills up that Space which ſeparates them. Therefore there is no Vacuity, neither ſmall nor great.

Ariſt. Condenſation at leaſt ſuppoſes there are ſome.

Eud. What is Condenſation? It is that Action which makes a Body diminiſh in Bulk, but not in Maſs; or which makes the ſame Body ſeem to poſſeſs leſs Space than it did, without loſing ought of its proper Matter. But Compreſſion

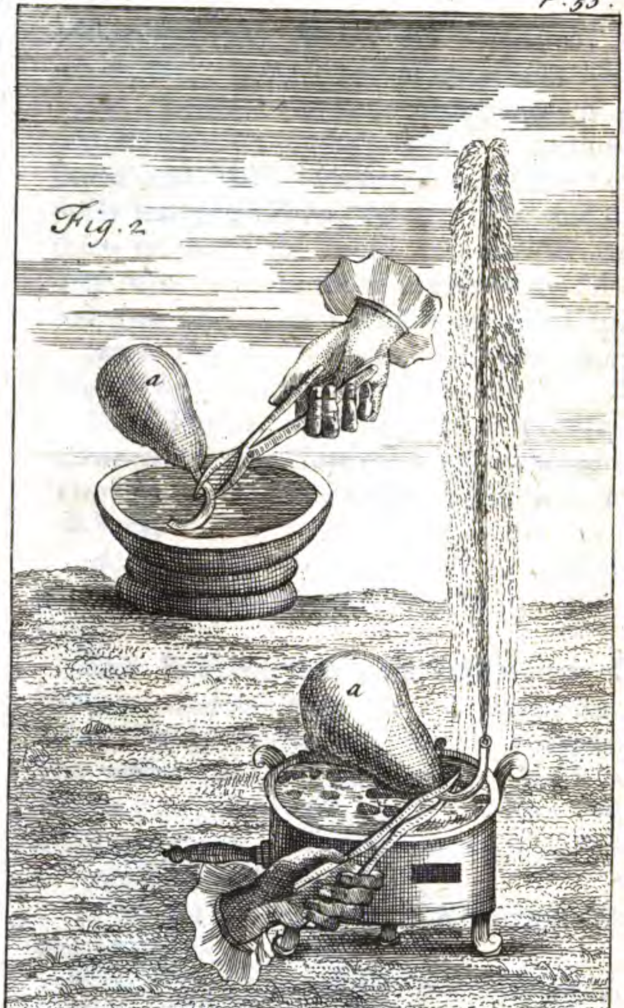

Fig. 2

IV. i.

preſſion expels the Air or ſubtile Matter out of it; at the ſame Time the Extremities of the Pores approach one another: And thus a Body is condenſed without a *Vacuum.*

Ariſt. Would you then explain without a *Vacuum* whatever is moſt ſurprizing in the Eolipile *(a) Fig.* 2?

Eud. The Eolipile is a ſort of Veſſel commonly made of Braſs, in the Form of a Pear, having in the ſharp End a ſmall crooked Pipe. At firſt they ſet the Eolipile upon a quick Fire: The ſmall Corpuſcles of Fire, which inſinuate themſelves through the Pores of the Braſs, dilate the internal Air by their violent Agitation, drive it out likewiſe, at leaſt in Part, through the ſmall Pipe, and take its Place. Then they take off the Eolipile from the Fire. You put the End of the little Pipe into Spirit of Wine. The Corpuſcles of Fire that are moſt agitated ſeek ſome Vent; they find it in the Pores through which they entered, and then iſſue out. The dilated Air is cooled and contracted. Hence the Spirit of Wine being puſhed forward by the external Air, and finding little Obſtruction in the Content of the Veſſel, where every Thing eaſily gives Way, flows into it proportionally as the Air is contracted, and as the Corpuſcles of Fire iſſue out. Finally the Eolipile is ſet again upon a quick Fire. The Corpuſcles of Fire penetrate it, inſinuate themſelves into the Pores of the dilated Liquor, and dilate them, by dilating the

Air which they encounter: The Liquor being dilated, and not finding Space enough in the Eolipile, is forced out abundantly through a very narrow Tube; it ſpouts out. Put a lighted Wax-Candle to it, and the Liquor catches Fire, and you behold with Aſtoniſhment a Spout of Fire that is darted into the Air, and its falling down again preſents to the Eyes a burning Shower. This is the fineſt Effect of the Eolipile. What Appearance of a *Vacuum* do you ſee in it?

Ariſt. But what ſignifies it to fill every Thing with ſubtile Matter or imperceptible Bodies, if you muſt indiſpenſably acknowledge Thouſands of Interſtices, or empty Paſſages in ſome Part or other? Now this you muſt do; and you go about it like a true Philoſopher, that is to ſay, with a good Grace. For the Voice, with which this Room has reſounded ever ſince our Converſation, ought to penetrate, and perhaps prove troubleſome, in the next Room: How does it penetrate thither, if the Wall does not afford it a Thouſand and a Thouſand free Paſſages; and how are thoſe Paſſages free, if they are not empty?

Inter ſepta meant voces, & clauſa domorum
Tranſvolitant ——
Eſt igitur nimirum quod ratione ſagaci
Quærimus, admixtum rebus quod inane vocamus.

Thus *Lucretius* reaſons. You will not hold it out againſt thoſe Verſes; the Taſte of Truth has not made you loſe the Taſte of Poetry; you love Verſes becauſe they adorn the Truth.

Eud. The Truth is rarely found adorned by the Verſes or elegant *Latin* of *Lucretius.* He might ſay as he pleaſed, that the Voice has no other Way but to make Vacuities in order to paſs into the Neighbourhood: it is ſufficient that the Air, which fills the Cracks and Pores of the Wall, communicates both with that which we breathe, and that of the adjacent Room. The Particles of this Air ſucceſſively carry the Voice to another Place, and report our philoſophical Diſputes.

Ariſt. Fill a Glaſs Tube of 36 Inches, or an 100, if you pleaſe, with Quickſilver; turn it into a Veſſel already full of Quickſilver; that in the Tube deſcends, and ſtops, as of itſelf and of Choice, at the Height of 27 or 28 Inches. In a Pump the Water aſcends and follows the Piſton to the Height of 32 Foot, or thereabouts; then it ſtops, and lets the Piſton aſcend alone as long as you will. What is it which fills up that Place which the Quickſilver and Piſton leave? You would not have ſmall Vacuities provided by Nature for letting the Voice paſs; lo, here is one of more than 50 Inches; what ſay I? of 50 Foot at leaſt.

Eud. The ſubtile Matter is always ready to ſucceed the Quickſilver. From the Time it deſcends, the ſubtile Matter ſlips through the Pores of the Glaſs, and ſeizes the free Place in order to tranſmit the Light to our Eyes; and the ſame Reaſon determines it to get into the Place forſaken by the Piſton, the Moment that the Water ceaſes to follow it.

Ariſt. I foreſaw your Anſwer; and muſt indeed, ſoon or late, think as you do. You have nothing to do but ſpeak. The ſubtile Matter comes from all Parts to ſecond you, and leaves me nothing to reply.

Eud. You ſee, *Ariſtus*, as well as I, that a *Vacuum* is good for nothing. But the Motion of Bodies is a Source of curious and uſeful Events; Motion is the moſt fertile Property of Bodies. Motion carries Life into all the Parts of our Body; it makes the Light ſhine in our Eyes, fertilizes the Earth, covers it with Plants and Flowers, loads the Trees with Fruit, and makes the Sweetneſs and Charms of Spring ſucceed the Severities of Winter. Motion does in ſome Sort animate the World. Without Motion no more Commerce among Men, no more publick Shows, *Paris* would grow dull, every Thing languiſh, and the Univerſe become a formleſs Chaos. But Motion, that is ſo neceſſary and productive of Wonders, has its Eſſence, Properties and Rules: Without knowing them, we can know little of Nature; Nature is unveiled, whenever we know them. Let us meditate upon them for ſome Time, and whenever you pleaſe we will communicate our Sentiments upon this Head to one another. Let us meet in the great Walk of the *Tuilleries* to Morrow at five a Clock in the Evening. Sometimes Philoſophy takes Pleaſure in the Beau-monde; it diſcovers the Truth even in the very midſt of thoſe who are amuſed with Lies.

Ariſt. I ſhall repair to this new *Lyceum*; every Thing invites me thither, the Company, the Beauty of the Place; and the Charms of ſo fine a Walk cannot fail to afford you a true Idea of Motion.

CONVERSATION VI.

Upon the Nature of Motion.

Eud. AH! I am overjoyed to find you at the Place of Appointment. The Parterre, the Flowers, the Statues, wherein Art rivals Nature, thoſe Marbles almoſt animated, nor any Thing elſe could detain me longer, as ſoon as I ſaw you appear. You was walking there in a philoſophical Manner, and with an Air ſomewhat penſive. Did your Walk give you any agreeable Idea of Motion?

Ariſt. Nothing ſeems more clear at firſt than the Idea of Motion, and yet nothing is more obſcure when one comes to ſearch thoroughly into it. When I ſee the Motion of thoſe People, who upon the Terraſs calmly enjoy the Pleaſures of walking without Philoſophy, I imagine I have caught the Idea of Motion; I fancy I ſee it in the ſucceſſive Correſpondence of my Body to thoſe ſeveral Trees, or in the different Degrees of Diſtance it has with *Æneas* and *Scipio*[m]; but whenever I endeavour to examine this Idea, it either eſcapes me, or becomes obſcured. It is loſt in real Difficulties, or in thoſe Phantoms of Difficulties which the Mind often frames to itſelf for no other Reaſon, than to torment itſelf to no Purpoſe.

Eud. Some diſtinguiſhed Genius's have talked all their Life Time of Motion, without knowing it, or having any true Idea of it.

Ariſt. Pray, *Eudoxus*, explain to me the Idea you have conceived of it, and by the Light of yours, mine may be cleared up. Do you believe with *M. Deſcartes*, that Motion is preciſely the paſſing of one Body from the Vicinity of thoſe with which it is immediately ſurrounded, into the Neighbourhood of ſome others?

Eud. No; I cannot perſuade my ſelf that the Axle-tree of a Poſt-Chaiſe, which is con-

[m] Two Statues placed at the End of the great Alley.

ſtantly fixed in the Nave that immediately touches it, can go ſo ſwiftly, without Motion, from *Paris* to *Verſailles*. A Man who ſhould go round the Earth in the ſame Cloaths, would do it without moving from home. *M. Deſcartes* was probably in a laughing Humour, when he ſaid that the Earth carried rapidly about the Sun in a Vortex of ætherial Matter would not move round||.

Ariſt. Do you think you can find Motion in the ſucceſſive Correſpondence of one Body to divers others?

Eud. I believe not; for from the Beginning of our Walk, I ſee in theſe two double Rows of Cheſnut-trees a ſucceſſive Correſpondence to divers Bodies: Have they therefore the more Motion? Not at all, unleſs that while we walk on gravely, they advance with a majeſtick and imperceptible Pace; unleſs they are upon the Walk themſelves; and unleſs Fame[n] be coming to meet us, proportionally as we advance towards Fame.

Ariſt. I don't believe that Fame is in any Haſte to find me out; one has but little Employment for her, when one is only ſeeking after the Truth. But pray, when we approach towards Fame, there are new Relations of Diſtance

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|| I am apt to believe the Reaſon why *Des Cartes* gave ſuch an ambiguous Definition of Motion was, that remembring *Galileo's* being put into the Inquiſition for aſſerting the Revolution of the Earth, he was willing to avoid the ſame cruel Fate.

[n] A Statue.

ſtance between us; do theſe new Relations make any Species of Motion?

Eud. When we advance towards the Statue of Fame, the *Louvre* and *Paris* have new Relations of Diſtance with us, and yet are not the more moved in the leaſt; it is not very neceſſary that the Impreſſion of our philoſophical Walk ſhould ſet all the Statues of the *Tuilleries* a moving, and ſpread itſelf all over *Paris.*

Ariſt. But in Proportion as we advance, the *Louvre* and *Paris* are farther diſtant from us; and in the Separation and Removal of Bodies Motion is Reciprocal, according to the Judgment of *M. Deſcartes.*

Eud. I ſhould have been as well pleaſed if *Deſcartes* had ſaid that the Swallow, which repoſes itſelf upon the Cock of *St. Genevieve,* whoſe Church contains the Aſhes of that great Man, could not fly away but that the Cock muſt fly with it.

Ariſt. Tell me then, I pray, what the Motion of a Body is *?

Eud.

" * *Motion is a Tranſlation from one Place to another Place, or* " *a continual Change of Place.* Every Body has an Idea of it; " and Philoſophers have in vain laboured to find a Definition of " the ſimple Idea, and proved with a great deal of Pains, that " one may come to be ignorant of a Thing which otherwiſe " every Body knows.

" Place *is the Space taken up by a Body:* of which may be ſaid, " what has juſt been ſaid concerning *Motion.* It is Twofold; " *True* or *Abſolute,* and *Relative.*

" *Defini-*

Eud. It is an active Change of Situation in Relation to ſome Body conſidered as if it had only Exiſtence. By this active Change I underſtand the Aſſemblage of a Body, of divers Relations of Diſtance which it acquires ſucceſſively, and of an actual Force received into it,

" *Definition* 1. True Place is that Part of immoveable Space, " which a Body takes up.

" *Defin.* 2. Relative Place, which only can be diſtinguiſhed " by our Senſes, *is the Situation of a Body in Reſpect of other* " *Bodies.*

" True Place is often changed whilſt Relative Place is not, " and ſo reciprocally. Whence ariſes a *true* and *abſolute* Moti- " on, and another Sort called a *Relative* Motion. Whilſt a Bo- " dy moves, Time goes on.

" Time alſo is Twofold; *True* or *Abſolute*, and *Relative.* " *True* Time has no Relation to the Motion of Bodies, nor to " the Succeſſion of Ideas in an intelligent Being, but by its Na- " ture it always flows equally.

" *Defin,* 3. Relative Time *is Part of the true Time meaſured* " *by the Motion of Bodies*; and this is the only Time that our " Senſes perceive.

" All Motion may become ſwifter, as likewiſe a Body may " move ſlower than it did before; and it is very likely that " there is no Motion of Bodies wholly equable; whence it fol- " lows that *relative* Time differs from true Time, which never " flows faſter nor ſlower.

Defin. 4. *That Affection of Motion, by which a Body runs thro' a certain Space in a certain Time is called* Celerity *or* Velocity, which is greater or leſs according to the *Bigneſs* of that *Space,* to which it is always proportional.

Defin. 5. The greater Force is impreſſed upon a Body to make it change its Place, the greater is its Motion; and that Force is called the *Quantity* or *Momentum of Motion.*

Defin. 6. The Direction of Motion, *is in a right Line, which we ſuppoſe drawn towards the Place where the moving Body tends.*

Defin. 7. A Power *is any Force acting upon a Body to move it.*

Defin. 8. The greatneſs of that Force is called, the *Intenſity of the Power.* Vide Graveſande's Elements. c. 6.

and which alone can give it thoſe different Relations. Now Motion is a Conjunction of thoſe three Things, I can diſcern them all three exactly in the Motion of my walking.

1. I there ſee a Body; ſince this Motion is the Mode of a Body moved, and the Mode of a Body is nothing but a Body modified. 2. This Motion implies divers ſucceſſive Relations of Diſtance: For when I ſit down, no one will pretend to ſay that I advance toward *Æneas* or *Scipio*; becauſe no ſucceſſive Relations of Diſtance are perceived between us. 3. This Motion implies an actual Force, received into the Body moved, which is called the moving Force; for the different and ſucceſſive Relations of Diſtance alone, with theſe Trees for Example, or with any Statues, are not Motion, unleſs theſe Trees and the Statues of *Apollo*, *Diana* and *Orpheus*, which have every Moment divers Relations of Diſtance, and which are ſometimes nearer to us and ſometimes farther from us, walk along with us. There is nothing more that offers in the Motion of my Walk. Therefore Motion is an active Change of Situation, &c.

Whenever Bodies contained in the World change their Situation, they paſs, they are carried from one Point to another in this vaſt Space; for which Reaſon theſe Terms, *A paſſing or Carriage from one Place to another*, may be uſed, as they are, and we ſhall uſe them likewiſe in order to expreſs the Motion of thoſe Bodies.

Ariſt. The Lady who rides in her Coach over againſt us in the *Elyſian Fields*, does not then move, ſince ſhe acquires no new Diſtances with reſpect to her Coach.

Eudox. Motion is relative. She does not move with reſpect to her Coach, but moves as her Coach does with reſpect to us and the *Tuilleries.*

Ariſt. Can a Boat move upon the *Sein*, that is equally driven toward *Paris* and toward *Chaillot* by the oppoſite Forces of the Wind and Water?

Eudox. No.

Ariſt. Neverthelеſs it would have new Relations of Diſtance with the Air and Water every Moment.

Eudox. True: But then theſe would be only external Relations, and not produced preciſely by Virtue of any Force received into the Subſtance of the Boat itſelf.

Ariſt. Suppoſe a Man ſhould walk upon the Boat from Eaſt to Weſt, with a Velocity equal to that which carries the Boat from Weſt to Eaſt.

Eudox. This Man moves really with reſpect to the Boat, becauſe by an actual Force preciſely which he receives or finds within himſelf, he acquires different ſucceſſive Diſtance with reſpect to the different Parts of the Boat.

Ariſt. Theſe ſucceſſive Relations are they neceſſary to Motion? Suppoſe that the Hand of God ſhould make the Univerſe turn round upon its Center, and that all the Parts of the Univerſe keep the ſame Relations of Diſtance among themſelves: The Univerſe would then be in Motion without acquiring any new Relations of Diſtance, ſeeing there is no Body at all beyond the Bounds of the Univerſe.

Eudox. 1. At preſent we have to do with the Motion of particular Bodies only, and not with the Motion of the whole World; and this Hypotheſis is good for nothing but to throw into the Mind vain Appearances of Difficulties. 2. According to this Suppoſition I imagine the Univerſe would move round, and not move; ſince it would have no new Relations of Diſtance.

Ariſt. One Hypotheſis more, *Eudoxus,* and do not loſe all Patience. There is need of Courage and Conſtancy, when one undertakes to inſtruct others. One Word only, and I yield. There are two Balls at once created out of this World, and ſituated ſo that in the firſt Inſtant you may put betwixt them a third Ball of a Foot diameter, which you cannot do in the Second: Do you obſerve any Motion there?

Eudox. Why ſhould I not? I ſee new Relations of Diſtance produced by Virtue of a moving Power, received at leaſt into one of the two Balls.

Ariſt. Which of the two is moved?

Eudox. That only which receives the moving ying Power; but both, if the moving Power be divided betwixt them.

Ariſt. I think at laſt I conceive the Nature of Motion in general: I go into your Sentiment, *Eudoxus*; therein I find wherewith to reſolve my Doubts, and to extricate myſelf from the trifling Cavils which an exceſſive Subtlety might raiſe.

Eudox. Very good! Let us now then define the ſeveral Kinds of Motion.

Ariſt. As for the ſeveral Kinds of Motion, I am able to define them. I apprehend what Motion is ſtraight or crooked, perpendicular, oblique, horizontal, circular, elliptic, parabolical, proper, common, ſimple, compound, direct, *&c.*

1. Motion is ſtraight, crooked, perpendicular, oblique, *&c.* according to the Line which it deſcribes. Should it deſcribe a ſtraight Line, it is ſtraight. Should it deſcribe a crooked Line, it is crooked, *&c.* The Motion of this *Jet d'Eau*, which inclines neither to one Side nor the other, and whoſe Waters fall back upon themſelves, is ſtraight and perpendicular. The Bullet would go from this Place with an oblique Motion in Search of the Turtle perched upon the Top of that Tree at twenty Paces diſtance from us. It would go in an horizontal Motion to ſtrike that Partridge which files off at about the Height of the Sportman's Eye. We walk from one end of this Alley to another in a Motion horizontal, or parallel to the

Horizon. Turn round a Circle, or round the Star °, and the Motion will be circular. Make a Tour exactly round a Ship, 'tis an elliptick Motion. The Caſt of a Bomb is parabolical. Turn round a Point always moving proportionally from it, and this will be a ſpiral Motion. 'Tis by this Motion the Snake encompaſſes its Head with the Folds of its Body.

2. Proper Motion is the particular Motion of a Body; common Motion carries forward ſeveral Bodies at once. Every one of thoſe Horſes in that Coach has his proper Motion; but the Motion of the Coach and of the Perſons who paſs in it along the *Sein*, is a common Motion. Theſe are two Motions which are no Way contrary: For while a Coach goes from *Paris* toward the *Elyſian-Fields*, a Fly walks at Liberty upon the Roof of it from the *Elyſian Fields* toward *Paris*. Thus upon a Veſſel under full Sail, one may walk with the ſame Eaſe from Prow to Stern, as from Stern to Prow.

3. Direct Motion is that which proceeds immediately from the Cauſe of Motion; reflected Motion, or Reflexion, is a Motion whereby a Body recoyls upon encountering another. The Motion of Refraction, or Refraction, is a Motion by which a Body leaves the direct Line in paſſing from one Medium into another, for Example from the Air into Water;

° A Walk near the *Elyſian* Fields.

ter; I throw a Stone obliquely upon the Surface of the *Sein*; this is a direct Motion: The little Stone recoils toward the other Bank; this is a Motion of Reflexion. Shoot off a Gun into the Water the Ball penetrates, but quitting the ſtrait Line; this is a Motion of Refraction.

4. Should the Motion proceed but from one Cauſe, and be directed but to one Point, it will be a ſimple Motion. Should it proceed from ſeveral Impreſſions, each in particular capable of giving it a Direction, then it would be compounded. The Motion of an Arrow which ſhould go in a perpendicular Line to pierce that Bird which hovers in the Air, would be ſimple; but the Motion of your Billiard-Ball, when it goes to hazard mine, is compounded of a ſtrait Motion which you give it, and of a Motion circular and upon its own Center, which is given it by the Inequalities of the Plane. Every Wheel of this Coach, the Splendour whereof is a Trophie of Vanity, unites two Motions in one compound Motion, the one circular which the Reſiſtance of the uneven Pavement gives it, and the other horizontal which proceeds from the Horſes, and makes it advance with ſo much Velocity and Noiſe.

5. They call that a perpetual Motion whoſe Production ſhould be the Effect of Art, and which ſhould no longer need the Aſſiſtance of Art to be perpetuated; ſuch would be the Mo-

tion of a Watch whoſe Spring would unbend and bend again, and mark out the Hours without any one's touching it. I leave you the Care of finding out this Motion. All the Philoſophers are ready to pay to you their Tribute of Praiſes; and the *Dutch*, faithful in keeping their Promiſes, will be forward to beſtow on you a Share of that Wealth which they go to ſeek for in the *Indies*.

Eudox. I chuſe rather to repoſe my ſelf, than loſe Time in ſearching for it; let us ſit down and diſpoſe our ſelves to diſcourſe of the Properties which are to be met with in the different Kinds of Motion.

Ariſt. Come then let us ſeat our ſelves, upon Condition that during the Time of our Repoſe you will tell me in one Word what is Time and Reſt. I own that when I aſk what Time and Reſt is, I think I know them; but if any Perſon ſhould aſk me, I have then no longer any Knowledge of them.

Eudox. Time is the ſucceſſive Duration of Things created and changeable; let me examine into the Idea of Time never ſo much, this is all it preſents to the Mind. The Parts of this ſucceſſive Duration are Moments, quarters of Hours, half Hours, Hours, Days, Months, Years, *&c.*

As for Reſt, it is the continual Preſervation of the ſame Relations of Diſtance with the ſame Parts of Extenſion. Hence two Sorts of Reſt, the one abſolute, and the other relative.

Relative Reſt is preciſely the continual Preſervation of the ſame Relations of Diſtance with certain Parts of Extenſion. Thus relative Reſt does not in the leaſt exclude Motion; a Man who ſleeps ſoundly in a Veſſel is in relative Reſt with reſpect to the Veſſel, becauſe he preſerves the ſame Relations of Diſtance with the Parts of the Veſſel; but he is in real Motion in regard of a thouſand other Bodies, with which he acquires new Relations of Diſtance by the ſole Virtue of a moving Power which he receives in himſelf. What is abſolute Reſt? It is the continual Preſervation of the ſame Relations of Diſtance without a Power whoſe Efficacy alone can give new Relations. Is there any abſolute Reſt in the Univerſe? There is nothing that demonſtrates it; for the imperceptible Parts of Bodies, which we look upon as Bodies in reſt, may be in real Motion.

But, *Ariſtus*, my dear *Ariſtus*, I ſee an Impertinent who comes directly up to us to diſturb and interrupt our Converſation; I am under a Neceſſity of hearing him, and ſpeaking a Word to him in private. Farewell; to Morrow at the ſame Hour, and in this ſame Place, we will examine the Properties of Motion.

CONVERSATION VII.

Upon the Properties of Motion.

Ariſt. I Muſt acknowledge, *Eudoxus*, it is much eaſier to walk than to comprehend well what walking is. One often walks without knowing what one does. I admire the Tranquillity of thoſe People whom I ſee taſting the Pleaſures of walking without any Solicitude about the Nature and Properties of their Motions; tho' I no wiſe envy them. The Pleaſure of conceiving what walking is, has ſomething in it more agreeable than the Pleaſure of walking itſelf. Thanks to your Inſtructions I know pretty well the Nature of Motion in general, and of the ſeveral Kinds of it: But what Method will you take to unfold its eſſential Properties? Do it I beſeech you, as preciſely as you can. I will liſten to you, without interrupting you. I find more Satisfaction in hearing you than in ſpeaking my ſelf. When I hear you, I imagine I am liſtening to Reaſon itſelf.

Eudox. Let us lay aſide all Complements; they are very ſeldom accompanied with Truth.

All Bodies, *Ariſtus*, that are moved, advance towards one Place, rather than another. They do not advance without running through ſome Space in a certain Time. They do not run through this Space without having ſome Force diffuſed through all their Parts, in order to overcome all Obſtacles. Hence there are three eſſential Properties of Motion, the Determination, Celerity and Quantity.

1. What is the Determination of Motion? It is the Direction of Motion towards one Side rather than another; for Example, toward the *Invalids*, rather than the *Place des Victoires*; toward *Paris*, rather than *St. Cloud*; toward the Eaſt, rather than the Weſt. There are two Sorts of Determinations, the one Simple, the other Compound. The firſt proceeds but from one Cauſe, from one ſingle Impreſſion, which directs the Body towards one particular Place: The other from ſeveral, capable of directing it towards different Places. The Direction which my Soul gives my Body towards *Apollo*, [p] rather than towards *Diana* [q], is a ſimple Determination or Direction. When you paſs over the *Sein* obliquely from the *Quatre Nations* to the *Louvre*, the Boat receives from the Rowers and the Water two Impreſſions, for the following two Lines, which would make a Square: The Impreſſion of the Rowers carries it toward the Point of the other Bank directly oppoſite; the Impreſſion of the

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[p] [q] Statues.

Water toward the *Pont-Royal*, according to the Current of the Water itſelf. The Boat yields, in ſome Meaſure, to the two Impreſſions, takes the middle Courſe, and gains the Bank in an oblique Line; and this Determination or Direction is compounded.

2. What is the Velocity of Motion? It is the Relation of the Motion both to the Length of Time, and of the Space run through in a certain Time; the Velocity anſwers to the Length of Time and Space. Why do they term the Celerity of a Thunderbolt immenſe? Becauſe it comes inſtantly from the Cloud to ſtrike the Head of a Criminal.

There are two Sorts of Velocity; the one abſolute, the other relative. Abſolute Velocity is the Celerity of a Body conſidered without Relation to any other. Relative Velocity is the Celerity of one Body conſidered with Relation to ſome other. The Velocity of my Pace, conſidered preciſely as the Velocity of my Pace, is abſolute Velocity; but the Velocity of my Pace, conſidered as exceeding yours, and unpolitely leaving you behind, is a relative Velocity. Would you meaſure Velocity, whether abſolute or relative? Have no Regard either to the Maſs or the Bulk. The Maſs, or Quantity, is the Collection of ſolid Parts, which compoſe the Body; the Bulk is the apparent Extent of thoſe Parts. The Celerity is neither meaſured by the Collection of ſolid Parts, nor by the Extent which ſtrikes the Senſes.

This

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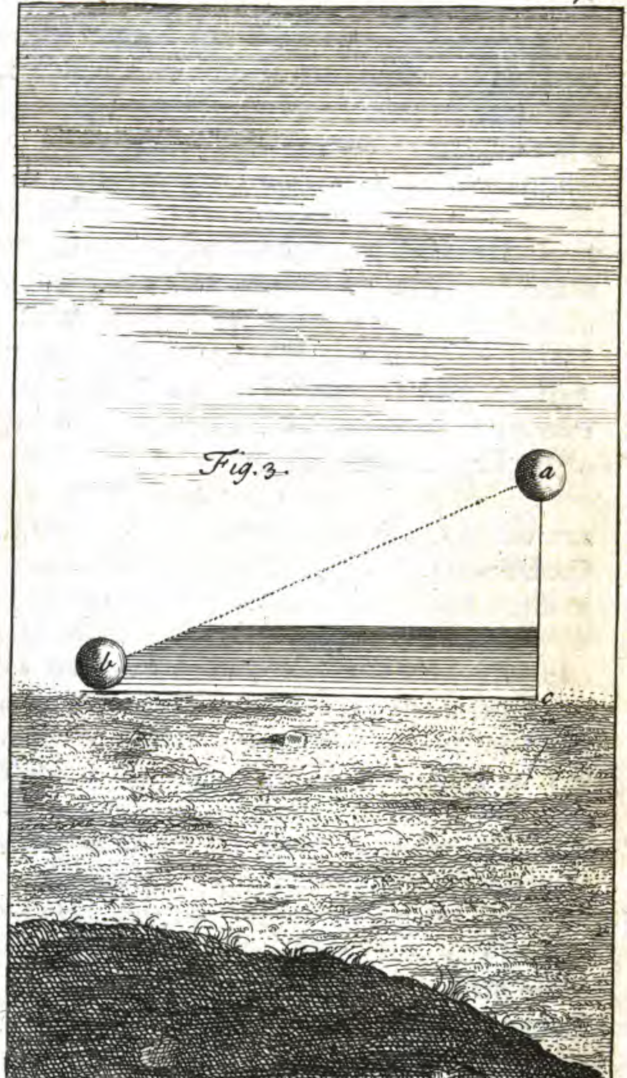
Fig. 3.



This Perſon here out of Breath, who is ſcarcely able to bear himſelf along, ſo much Maſs and Bulk has he, ſhews more of it to Appearance than any Body; does he move then with the greater Celerity?

By what then is the Velocity meaſured? By the Length of Time, and of the Space run through. Divide, as you pleaſe, the Length of this Space into ſeveral Parts; into Points, Inches, or Feet which are called Degrees: The Degrees run through in a certain Time, expreſs the Degrees of the abſolute Velocity of a Body.

Should two Bodies remove from one another, or advance towards one another; add the Degrees of the abſolute Celerity of the one, to the Degrees of that of the other, and you will have in the Addition their relative Velocity. Should one Body follow another with ſome Exceſs of Velocity, this ſame Exceſs is the relative Velocity of thoſe Bodies. In a Word, 'tis by this Exceſs only that they approach nigher to one another. Should one Body fall in a perpendicular Line upon another, its relative Velocity is the ſame with its abſolute. Should it fall in an oblique Line upon an immoveable Plane, *Fig.* 3. its relative Velocity is meaſured not by the Length or Degrees of the oblique Line run through *(a b)*, but by the Length or Degrees of the perpendicular Line *(a c)*, drawn from the Point from which it falls, to the Plane itſelf; becauſe the

Exceſs of the oblique Line above the Perpendicular is of no Service in approaching towards the Plane.

3. What is the Quantity of Motion? It is that Force with which it ſtrikes Bodies which happen to encounter it. There are two Sorts of Quantity; the one abſolute, the other relative. The Firſt is a Quantity conſidered preciſely in itſelf; the Second is one Quantity compared with another.

The Quantity of Motion, whether abſolute or relative, is equally meaſured, both by the Maſs or Greatneſs, and the Celerity. For, in ſhort, the Quantity of Motion is the Force of a Body moved: And the Force of a Body moved, is meaſured equally by thoſe two Things; ſince the ſame Exceſs of Maſs or Celerity, produces the ſame Exceſs in the Shock. Let a Body of two Pounds move with the Velocity of four Degrees, or let a Body of four Pounds move with the Velocity of two Degrees, the Preſſure is the ſame in its encountering another Body. Therefore the Quantity of Motion is equally meaſured both by the Maſs and the Celerity.

In a Word, the Quantity of Motion is equally meaſured, both by the Maſs and the Velocity, if the Force which carries a Body of two Pounds in one Moment to a Foot Diſtance, and a Force which carries a Body of one Pound in the ſame Moment to two Foot Diſtance, are equal Forces: But theſe are equal

qual Forces; for that Force which carries a Body of two Pounds in one Moment to one Foot Diſtance, is a Force which in one Moment carries one Pound to one Foot Diſtance, and another Pound to another: The Force which carries one Pound to two Foot Diſtance in an Inſtant, is a Force which in an Inſtant carries one Pound to one Foot Diſtance, and the ſame Pound to another Foot: But the Force which in an Inſtant carries one Pound one Foot, and another Pound to one Foot; and the Force which in an Inſtant carries one Pound to one Foot, and the ſame Pound to another Foot, are equal Forces: Therefore the Force which in an Inſtant carries a Body of two Pounds to one Foot diſtance, and the Force which in an Inſtant carries a Body of one Pound to two Foot Diſtance, are equal Forces; therefore the Quantity of Motion is equally meaſured both by the Maſs and the Velocity. In like Manner, Experience teaches us, that in order to move a double Body with the ſame Celerity, or the ſame Body with a double Celerity, we muſt equally double the Forces.

If the Queſtion be to determine the relative Quantity of Motion, in order to that I begin with dividing the Velocity of two Bodies into equal Degrees; then I likewiſe divide at Pleaſure the Maſs into equal Degrees or Parts, *e. g.* into Pounds. Then I multiply the Degrees of the Maſs of each Body by the Degrees of Velocity, or the Degrees of Velocity by the Degrees of the Maſs. The Product of each Multiplication gives us the Quantity of the Motion of each Body. Is the Velocity of a Body 4 Degrees, and the Maſs 3? I muſt multiply 4 by 3, or 3 by 4. The Product is 12. And this is 12 Degrees of Motion. Is the Velocity of the other Body 2 Degrees, and the Maſs 4? I multiply 2 by 4, it produces 8. Thus I determine the Force of one Body with Reſpect to another.

Ariſt. But I don't yet clearly ſee how the Product of the Velocity by the Maſs, or of the Maſs by the Velocity, expreſſes the Quantity of Motion.

Eud. The Force or Quantity of Motion gives every Part of the Maſs its Velocity, equal to the Velocity of the Maſs in general; ſince in the ſame Time every Part runs the ſame Length of Way as the whole Maſs. Therefore the Force anſwers to the Number of Parts, and to the Velocities of the Parts, or to the Degrees of the Velocity of the Maſs, taken ſo many Times as the Maſs has Parts. Therefore the Product of the Velocity, multiplied by the Degrees of the Maſs, or the Maſs multiplied by the Degrees of Velocity, ought to expreſs exactly the Quantity of Motion, or the Degrees of Force, which are found in the Body.

Ariſt. I perfectly apprehend your Meaning. The Determination of Motion is its Direction towards one Part rather than towards another. The Velocity of Motion is its Relation to the

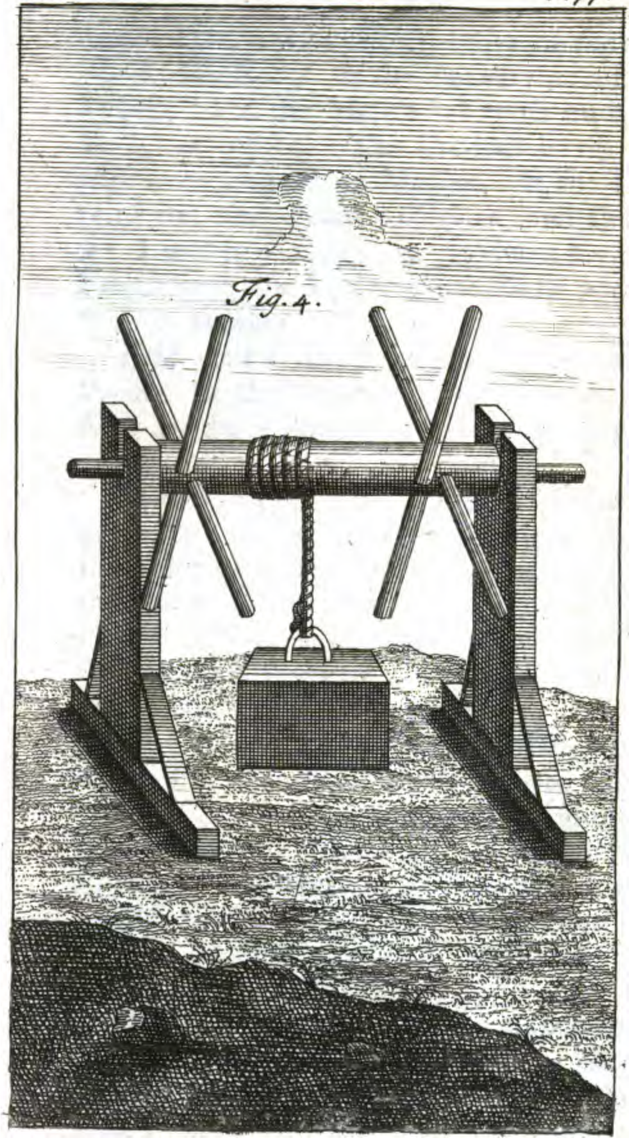


Fig. 4.

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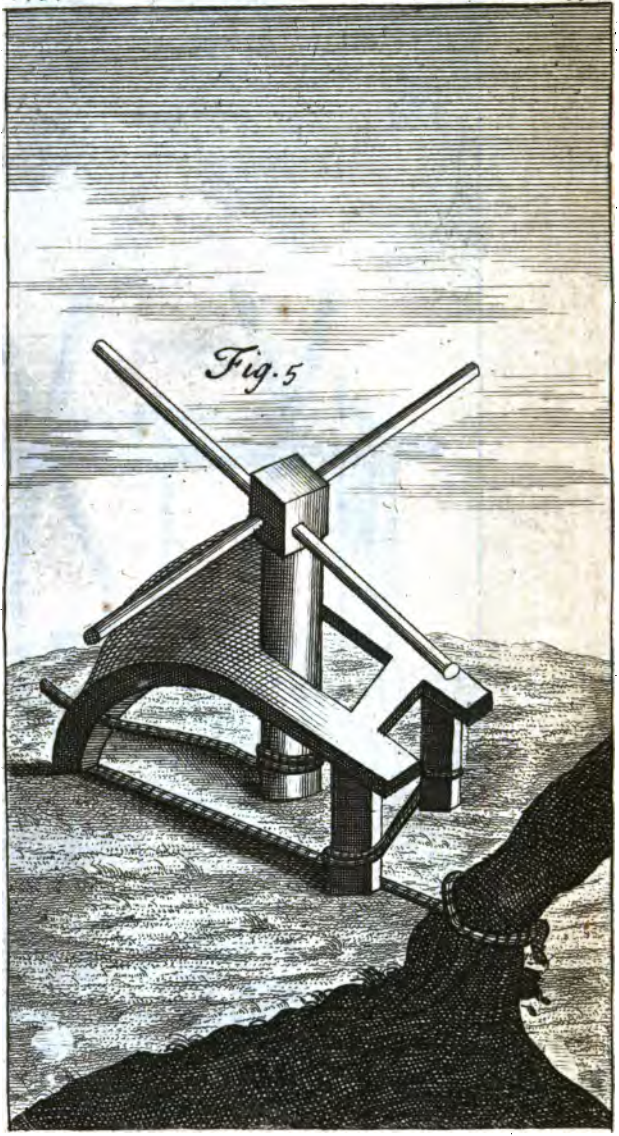

Fig. 5

greater or ſmaller Length, both of the Time and of the Space run through in that Time. The Quantity of Motion is its Force expreſs'd by the Product, either of the Velocity by the Maſs, or of the Maſs by the Velocity.

Eud. Hence when two unequal Bodies are in a reciprocal *Ratio*, that is, when the one has more or leſs Maſs, in Proportion as the other has more or leſs Celerity, they have equal Quantities or Forces of Motion. Are they not in a reciprocal *Ratio?* Their Powers are unequal. Though I walk this Moment as ſlowly as you do, or have preciſely the ſame Celerity that you have, yet I have more Motion than you, becauſe I have more Height, and you have a Shape more ſlender and thin. This is the general Principle of Mechanicks, a Science ſo happy for improving Arts by the Knowledge and Help of Machines, eſpecially ſince the Foundation of the Royal Academy of Sciences. In this Principle alone you find at once the Knowledge of the ſurprizing Effects which the Curious take Pleaſure to obſerve in divers Leavers, in the *Roman* Ballance, Oars, Jacks, the Wheels of Water-Mills, the Wings of Wind-Mills, the Handle of Coffee-Mills, the Roll of an Hand-Mill, *Fig.* 4, the Capeſtan, *Fig.* 5. the Poles of Rope-Dancers, the Wedge, *&c.*

Ariſt. What Method do you take, *Eudoxus*, to find at once in this ſingle Principle the

Knowledge of ſo many Things, which as yet appear to me unintelligible?

Eud. In a Machine I diſtinguiſh the Center, the Diſtances, and the Weight. I call the Center a fixed Point, or Point of Suſpenſion, the Point by which the Machine is ſupported, faſtened, or ſuſpended. I call the Diſtance or Beam, the Line or Extent which is found between the fixed Point and the Extremity of the Machine. I call the Weight, the Forces or Bodies applied after ſuch a Manner to divers Points of the Machine, that they counteract one another. The common Ballance, *Fig.* 6. preſents to the Mind at firſt View a Center, or fixed Point, or Point of Suſpenſion *(a)*, Diſtances or *Radii* *(b, c)*, and Weights *(d, e)*. Finally, I call *Æquilibrium*, Reſt or Immobility, produced by Cauſes which have a contrary Tendency, but are of equal Forces, and equal Motions.

Two unequal Weights being ſituated in a Machine, after ſuch a Manner, that the leaſt of them is farther diſtant from the Center or fixed Point, in Proportion as it has leſs Bigneſs, they cannot move round the Center, but there muſt be in the leaſt an Exceſs of Velocity, equal to the Exceſs of Maſs which is found in the greater. The Exceſs of Velocity anſwers to the Exceſs of Diſtance or Beam; ſince the Parts of the Beam move ſo much the more ſwiftly, the farther diſtant they are from the Center, as is evidently ſeen in the *Radii* of

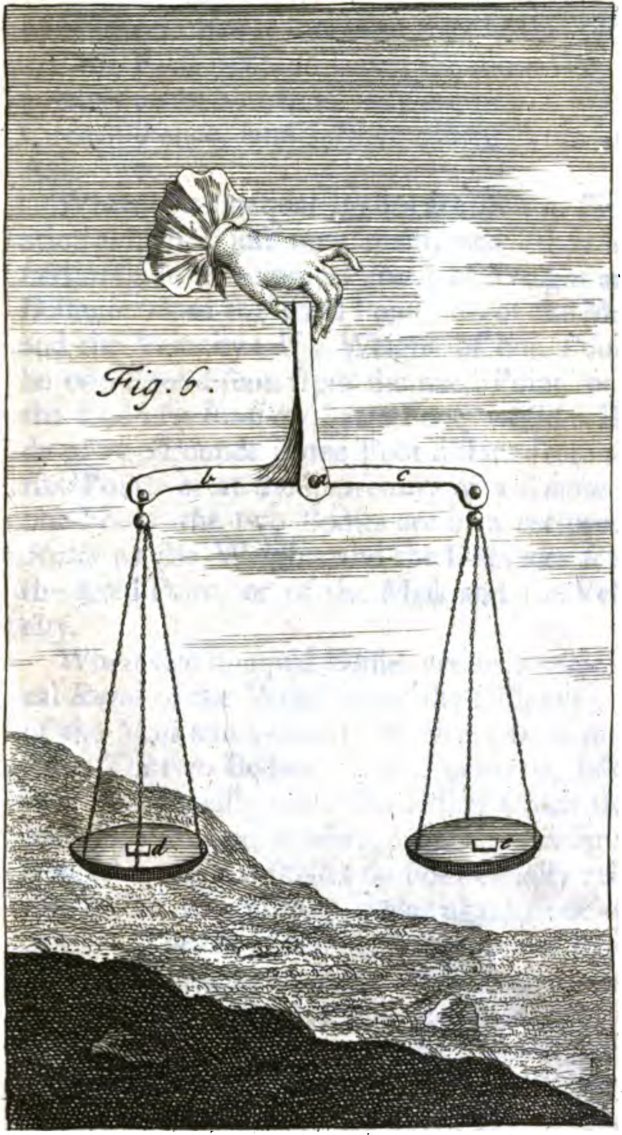

Fig. 6.

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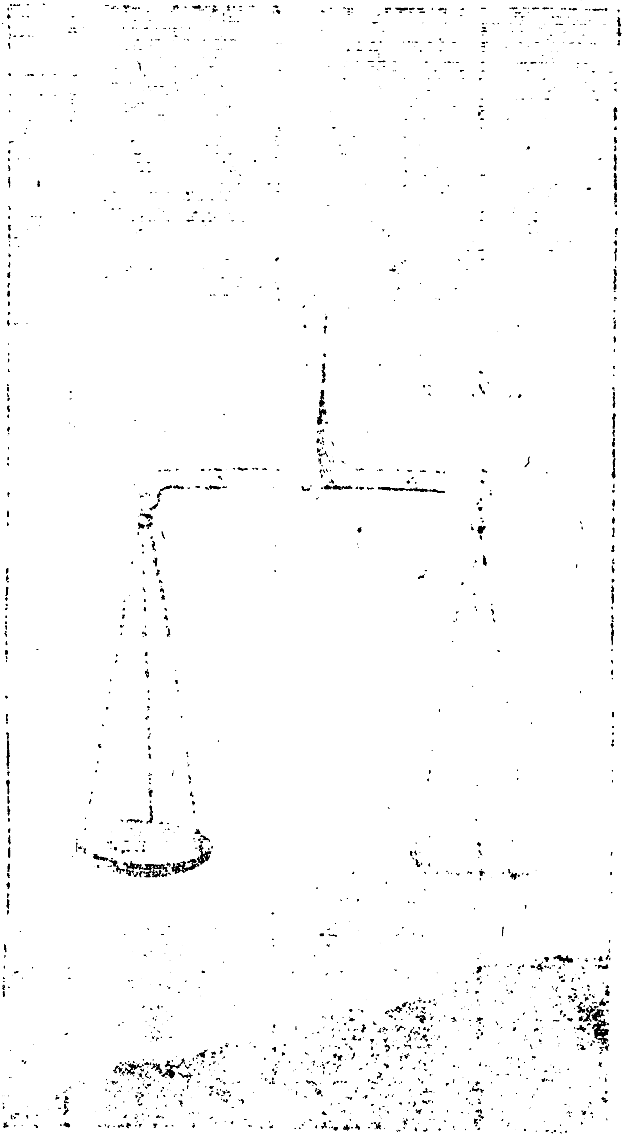


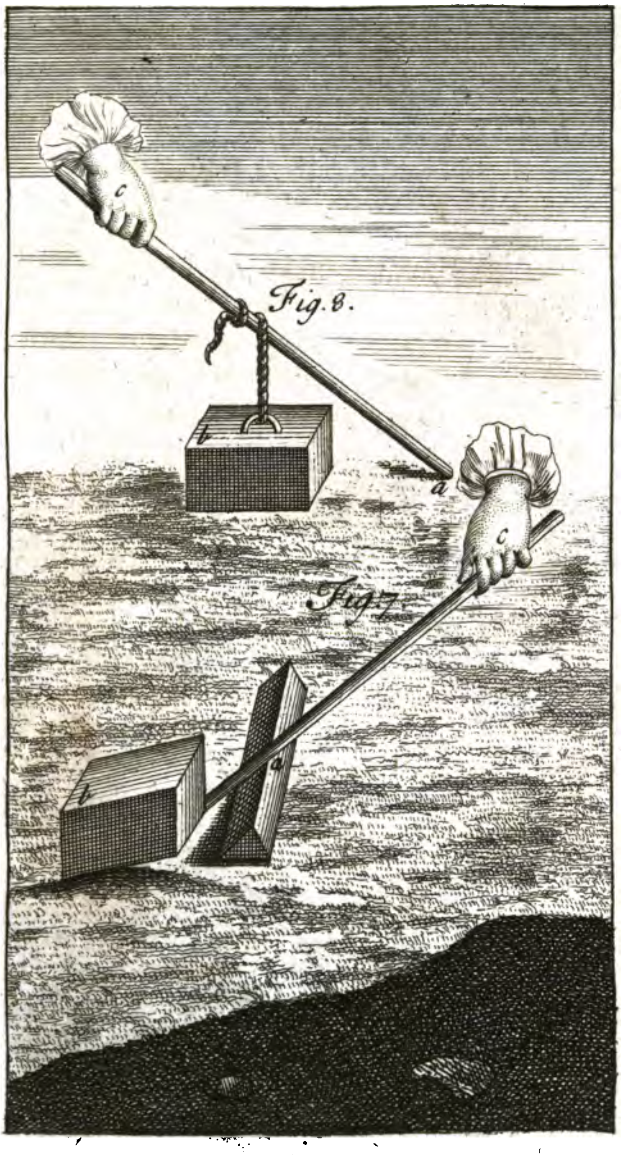
of a Wheel: For it is evident that in theſe *Radii*, the Parts make ſo much the more Way in a determinate Time, as they are nearer to the Circumference, and farther diſtant from the Axle-Tree.

When two unequal Bodies are in the Situation which I juſt now mentioned, they are ſaid to be in a reciprocal *Ratio* of Weight and Diſtance from the fixed Point, or of the Maſs and the Velocity: If a Weight of one Pound be two Foot diſtant from the fixed Point, or at the End of a *Radius* of two Foot, while a Body of two Pounds is one Foot diſtant from the fixt Point, or at the Extremity of a *Radius* of one Foot; the two Bodies are in a reciprocal *Ratio* of the Weights and the Diſtances from the fixed Point, or of the Maſs and the Velocity.

When two unequal Bodies are in a reciprocal *Ratio* of the Weights and the Diſtances, or of the Maſs and Velocity, they are *in Æquilibrio:* For two Bodies are *in Æquilibrio*, when they both equally reſiſt the Effort which they make againſt one another. But in this Situation two unequal Bodies do both equally reſiſt the Effort which they make againſt one another. The Reſiſtance is equal to the Motion neceſſary to move them; and to move them there needs an equal Force, an equal Quantity of Motion, ſince there muſt be ſo much more Swiftneſs in the leaſt, as there is more Maſs in the greateſt, and ſince the Force and Quantity of Motion are equally meaſured by the Velocity, and the Maſs, as we have demonſtrated.

Since two unequal Bodies are *in Æquilibrio*, when they are in a reciprocal *Ratio* of Weight and Diſtance; by a contrary Reaſon they are not *in Æquilibrio*, when they are not in a reciprocal *Ratio*. If they are not *in Æquilibrio*, that muſt give Way which makes the leaſt Reſiſtance, that which requires leaſt Motion to move it, reſiſts leſs; therefore it ought to give Way, and conſequently the other ought to outweigh it.

This being granted, one may immediately conceive the Efficacy of divers Leavers. The Leaver in general is a long Body, of which the Length only comes under Conſideration. It has its fixed Point, and two Weights; or one Weight, which is called the Reſiſtance, and a Force equivalent to a Weight, which is called the Power, ſuch as the Hand when applied to one End of the Leaver. If the fixed Point *(a)* *Fig*. 7. be between the Reſiſtance *(b)*, and the Power *(c)*, it is a Leaver of the firſt Species. If the Reſiſtance be between the Power and the Point of Suſpenſion, it is a Leaver of the Second, *Fig*. 8. Theſe two Species of Leavers are effectual; why? Becauſe the Power both in the one and the other may be ſufficiently removed from the Center or fixed Point, in order to have an Exceſs of Swiftneſs, equal or ſuperior to the Exceſs of the Greatneſs of the Reſiſtance,



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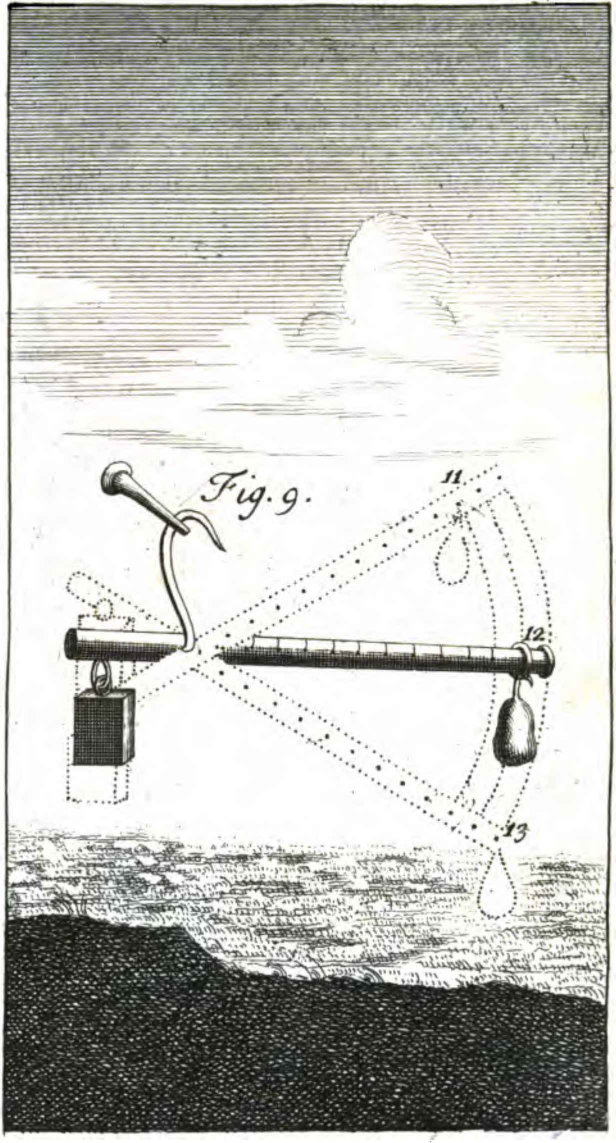

Fig. 9.

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Reſiſtance, or of the Weight; ſince the Velocity anſwers to the Length of the *Radius*.

Hence I can eaſily explain the *Roman* Ballance, *Fig.* 9. which is a Leaver of the firſt Species: The *Roman* Ballance has two unequal *Radii*, united and ſuſpended by a fixed Point. Suppoſe the ſmalleſt be one Inch, and the biggeſt thirteen. On the End of the ſmalleſt I faſten a Weight of twelve Pounds; to the eleventh Inch of the greateſt I apply a Weight of one Pound. This Weight yields and aſcends. I place it at the twelfth Inch, it remains *in Æquilibrio*. I advance it to the thirteenth Inch, it deſcends, and the other Weight aſcends. Why ought the Weight of one Pound to yield and aſcend at the eleventh Inch, remain *in Æquilibrio* at the twelfth, and outweigh and deſcend at the thirteenth?

1. The Weight of one Pound ought to yield and aſcend at the 11th Inch, if it makes a leſs Reſiſtance to the Effort of the Weight of 12 Pounds, than the Weight of 12 Pounds to the Effort of the Weight of one Pound: But it makes leſs Reſiſtance; for the Reſiſtance anſwers to the Force neceſſary to move it, and to move it there need be only eleven Degrees of Force or Motion, while 12 are neceſſary for 12 Pounds. In ſhort, while the Weight of 12 Pounds deſcends one Inch with one Degree of Velocity, the Weight of one Pound aſcends eleven Inches preciſely with eleven Degrees of Velocity: But a Weight of one Pound, which

has only eleven Degrees of Velocity, has only eleven Degrees of Motion; a Weight of 12 Pounds, which has one Degree of Velocity, has 12 Degrees of Motion; ſince the Motion is the Product of the Velocity by the Maſs, or of the Maſs by the Velocity, the Product of 12 Degrees of Maſs by 1 Degree of Velocity is 12, and the Product of 11 Degrees of Velocity by one Degree of Maſs, is but 11. Therefore the Weight of one Pound ought to yield, and aſcend at the eleventh Inch.

2. Why ought the Weight of one Pound to æquiponderate at the twelfth Inch? The Weight of one Pound ought to æquiponderate, if its Reſiſtance is equal to that of 12 Pounds: But it is equal; for to move both the one and the other, the ſame Quantity of Motion is neceſſary. The Weight of 12 Pounds cannot deſcend one Inch, but the Weight of one Pound muſt aſcend 12 Inches; a Weight of 12 Pounds cannot deſcend one Inch, nor a Weight of one Pound aſcend 12 Inches, without having each of them the ſame Quantity of Motion, that is to ſay, 12 Degrees: Motion is equally meaſured both by the Velocity and the Maſs, and one Degree of Maſs multiplied by 12 Degrees of Velocity, or one Degree of Velocity multiplied by 12 Degrees of Maſs, afford 12 Degrees of Motion: Therefore a Weight of one Pound ought to be *in Æquilibrio* at the twelfth Inch.

3. Why ought the Weight of one Pound to deſcend, being at the thirteenth Inch? The Weight of one Pound ought to deſcend, if the Weight of 12 Pounds muſt aſcend one Inch: But the Weight of 12 Pounds muſt aſcend one Inch, for it ought to yield and aſcend, if it reſiſt leſs; and it does reſiſt leſs, ſince it requires leſs Force to move it. In ſhort, it moves and aſcends one Inch with 12 Degrees of Motion, while the other moves and deſcends 13 Inches with 13 Degrees of Motion: For the 12 Degrees of Maſs of the one, with one Degree of Celerity only, make 12 Degrees of Motion; the 13 Degrees of Velocity of the other, with one Degree of Maſs, make 13 Degrees of Motion. Therefore the Weight of one Pound ought to yield, when it is at the 11th Inch; to remain *in Æquilibrio*, when at the 12th; and to outweigh, when at the 13th. Which was the Thing to be demonſtrated.

Ariſt. Since the Efficacy of the ſmalleſt Weight or Power, increaſes in Proportion to its Diſtance from the fixed Point, the ſmalleſt Weight, the leaſt Power which one can imagine, can then outweigh the Reſiſtance of the greateſt Weight?

Eud. I require no more, with *Archimedes*, than a fixed Point without the World, and a Leaver of a certain Stiffneſs and Length, and I will tranſport the Univerſe at Pleaſure into the imaginary Spaces. A Child would be able to do it by lightly touching the Leaver with the End of his Finger.

Ariſt. I am not ſurprized that Sciſſars cut better near the Rivet than toward the Point. Sciſſars are two Leavers of the firſt Species, faſtened by a Rivet, which is a fixed Point, or common Center; and the nearer the Reſiſtance is to the Point of Suſpenſion, the more eaſily it ought to yield. The Efficacy of Pincers proceeds from the ſame Principle; and I underſtand why, when with Pincers I lay hold of a Log toward one of its Ends, it riſes and obeys with more Difficulty, than when I lay hold on it by the Middle. When I lay hold of it by the End, the other End has ſo much the more Force to reſiſt, as it is more remote from the Pincers, and from the Point of Suſpenſion. But let us ſee the Uſe of your Principle in ſome Leavers of the ſecond Species.

Eud. The Oar, which makes this Boat paſs up toward the *Pont Royal*, is one. The Power is the Hand applied towards the other Extremity of the Oar; the Weight or Reſiſtance is the Boat and its Lading, attach'd to the Oar between the Power and the fixed Point. The Hand or Power has ſo much more Advantage above the Weight, as it is more remote from the fixed Point, or the Water, than the Weight itſelf.

Ariſt. But the Rower's Feet drive the Boat back with as great an Effort, as the Hand makes to carry it forward. Therefore the

Boat ought to be immoveable, at leaſt in ſtanding Water.

Eud. The Force of the Hand ought to prevail over that of the Feet, if the Force of the Hand be much farther removed from the fixed Point: But it is much farther removed from it. The fixt Point is in the Water, the Hand is at the other End of the Oar, and the Force of the Feet making a part of the Weight or Reſiſtance is, together with the Weight or Reſiſtance toward the Point of Reſt, united in the Point of the Oar where it is attach'd to the Boat; therefore the Force of the Oar muſt prevail over that of the Rower's Feet. And it is this Exceſs of Force which makes the Boat advance, and, contrary to the Current of the Water, carry Games and Diverſions toward the charming Manſions of *Berci*, *Conflans* and *Choiſi*.

Ariſt. I comprehend why the Hand of the Rower overcomes the contrary Effort of his Feet, and the Current of the Water.

Eud. But do you comprehend how the *Sein* makes this Mill turn round, and how the Water only of one ſingle Rivulet can make it turn, though it have much leſs Maſs and Bulk than the Mill-ſtone itſelf?

Ariſt. Let me think a Moment. Each *Radius* of the Wheel is a Leaver of the firſt Species. The Water which flows, and is precipitated into the ſmall Cells of the Circumference, is the Power applied to one of the Extremities of each *Radius*. Toward the other Extremity is the Point of Support, in the Center of a Cylinder, into which the *Radii* are ſet. The Weight or Reſiſtance is the little internal Wheel which immediately receives the Motion from the Cylinder that it conveys to the Mill-ſtone. The Power has ſo much the more Advantage over the Reſiſtance, as its Beam is the larger; and becauſe the Exceſs of Velocity in the Power does prevail, the Wheel turns round, the Grain is bruiſed, and diſpoſed to become proper Food for the Preſervation of our Lives.

The Windmill follows the ſame Principles; its Wings, which are agitated by the Wind are ſo many Leavers of the ſame Species, as is alſo the Handle of a Coffee-Mill. At length I conceive why one has ſo little Difficulty, and ſo much Pleaſure in the grinding of Coffee.

Eud. Now that which conſtitutes the Force of the Coffee-Mill, makes up the Force of the Roller, Capeſtan, Jack, *&c.* The Wedge paſſes for a double Leaver of the ſecond Species. The Nail, Knife and Sword are ſo many Sorts of Wedges, which are driven in ſo much the more eaſily, as the Parts ſeparated by thoſe Species of Wedges find in them whereon to ſupport themſelves in ſome Sort, as upon an inclined Plane. The Advantage of an inclined Plane is to be found in the Screw.

Ariſt. I ſee perfectly, *Eudoxus*, the Fertility of this Principle, that the Quantity of Motion is equally meaſured by the Maſs, and by the Velocity.

Eud. Well, ſince we have examined the Determination, the Velocity, the Quantity, and Properties of Motion, we will examine its Rules whenever you pleaſe.

Ariſt. To Morrow at ſix in the Morning I will repair to your Cloſet. I know that Philoſophers take little Reſt, their Search after Truth keeps them awake.

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CONVERSATION VIII.

Upon the general Rules of Motion.

Ariſt. I believe, *Eudoxus*, you will find ſome Difficulty in inſtructing me upon this Head. This Morning I ſaw a Man of Learning, well verſed in Antiquity, and who has by the ſole Weight of his Authority, filled me with ſtrong Prejudices againſt your Rules of Motion. He peremptorily affirms without any Ceremony, that thoſe Sorts of Rules are good for nothing, but to overturn the Order of Nature.

Eud. I know not whether your Man of Learning was well awake, for he ſeems to me to have been in a Dream. Perhaps I am deceived; but in Matter of Phyſics I don't think one is obliged to yield immediately to the ſole Authority of a learned Man. This Victory depends upon the Force of his Reaſonings. For my Part, I do not know what they are, but here are mine.

If Bodies do not follow, in their Motions, ſome conſtant Rules and Laws eſtabliſhed by the Wiſdom of the Creator, why do we ſee every Moment Bodies which move, and continue to move more or leſs, in Proportion as ſome foreign Cauſe comes to determine them ſooner or later to reſt? Why does every Body that moves circularly, get off in a right Line, whenever it is at Liberty? Why does a Body, which receives divers Impreſſions at one Time towards different Places, accommodate itſelf to them all, as much as it can, according as they are ſtronger or weaker? Why do we ſee it loſe ſo much the more Motion, the more it cauſes in other Bodies?

Ariſt. I freely acknowledge your Reaſons affect me more than the Authority of my Man of Learning, who has grown old in his Enquiries after Antiquity, but who ſeems never to have conſidered what Nature inceſſantly preſents to his Eyes.

Eud. The Author of Nature, *Ariſtus*, has made Laws both for Bodies and Spirits; and in the Obſervation of thoſe Laws I ſee a ſurprizing Difference: That is, that Spirits abuſe Reaſon, in order to violate theirs, while Bodies follow theirs conſtantly, and without degenerating, as if they were reaſonable.

Ariſt. Pray let us unfold thoſe Laws or Rules ſo faithfully obſerved by Bodies.

Eud. In order to do ſo, let us begin with laying down ſome Principles.

1. Motion and Reſt are the two States of Bodies: For conſtant Modes of Bodies are their States, and Motion and Reſt are the conſtant Modes of Bodies, ſince both the one and the other conſiſts in a Sort of Continuation; Motion in a ſucceſſive Continuation, and Reſt in a permanent Continuation.

Ariſt. According to this Principle, *Ovid* ſeems to have been a Philoſopher, and alſo ſomething of a *Carteſian*, when he found Conſtancy even in the Inconſtancy of Fortune:

Et tantum conſtans in levitate ſuâ eſt.

Eud. 2. Body can give itſelf neither Motion nor Reſt; and of itſelf is wholly indifferent as to the one or the other. In a Word, it has of its own Property no Force, no Efficacy; it is only a Portion of Extenſion: It has nothing of itſelf and of its own Stock beſide Length, Breadth and Thickneſs; the Idea of Body offers nothing elſe to the Mind.

3. As Body is indifferent either to Motion or Reſt, by the ſame Reaſon it is ſo either to ſuch or ſuch a Direction, or to ſuch or ſuch a Velocity.

Let us examine at preſent the general Rules, which all Bodies that are moved ſeem to follow in the Order of Nature: I ſee four of them †.

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† Sir *Iſaac Newton* has laid down three, by which we think every Thing that relates to Motion may be explained.

LAW I.

All Bodies continue in their State of Reſt or Motion, uniformly in a right Line, except ſo much as they are forced to change that State by Forces impreſſed.

To ſhew how inviolably this Law is obſerved, we need only conſider that no Inſtance has been ever produced of any Body that did of itſelf change from Reſt to Motion, nor from Motion to Reſt; nor when in Motion, alter its Courſe, but that whereever ſuch Changes happened, there were always evident Cauſes. If Bodies changed their Places of themſelves, all Things would run into Confuſion, nor would there be any certain Means to regulate the Actions of the Univerſe.

Moreover there is in Matter a paſſive *Principle*, which Sir *Iſaac Newton* very well expreſſes by the *Vis Inertiæ*, whereby Bodies reſiſt to the utmoſt of their Power, any Change or Alteration of their State, whatever it be, either of Reſt, Motion, or its Direction; and this Reſiſtance is always equal in the ſame Body, and in different Bodies is proportional to the Quantity of Matter they contain. There is required as much Force to ſtop a Body in Motion, as is required to put it in Motion, & *vice verſa*; and therefore ſince the ſame Body equally reſiſts the contrary equal Changes of its State, this Reſiſtance will operate as powerfully to keep a Body in Motion, as to keep it at Reſt, and conſequently of itſelf, it can never change its State of Reſt, Motion, or Direction; for to change its Direction, is the ſame Thing as to move of itſelf another Way. Matter then of itſelf is ſo far indifferent to Motion or Reſt, that it is no more inclined

Here is the Firſt: A Body that is moved, ought to continue in Motion, until ſome external and particular Cauſe determine it to reſt.

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to the one than to the other, and does no leſs reſiſt a Change from Reſt to Motion, than from Motion to Reſt. This *Vis Inertiæ* is no where more conſpicuous than in the ſudden Motion of a Veſſel full of Liquor upon a Horizontal Plane; at firſt while the Veſſel is moving along the Plane, the Liquor ſeems to move with a Direction contrary to that of the Veſſel, the Water riſing on the Hinder Side of the Veſſel. Not that there is really any ſuch Motion impreſſed upon the Liquor, but that by the *Vis Inertiæ*, the Water endeavouring to continue in its State of Reſt, the Veſſel can't immediately communicate its Motion to it, by Reaſon of its Bulk and fluid State: But the Liquor perſeveres in its State of Reſt, whilſt the Veſſel makes forwards, and ſo ſeems to move a contrary Way. But when once the Liquor has the Motion of the Veſſel intirely communicated to it, and begins to move with a Velocity equal to that of the Veſſel, if the Veſſel be ſuddenly ſtopped, the Liquor continues its Motion, and daſhes over the Sides of the Veſſel. This *paſſive* Principle, or *Vis Inertiæ*, is eſſential to Matter, and can neither be intended or remitted in the ſame Body, but is always proportional to the Quantity of Matter Bodies contain.

Corol. 1. Hence it is evident that no Body put in Motion will naturally, and of itſelf, move in a *Curve-Line*. For whatever moves in a Curve-Line, muſt in every Point alter its Direction, which, as was ſaid before, no Body can do.

Corol. 2. Hence the great Bodies of this Univerſe the *Planets*, their *Satellites*, and the *Comets* do not naturally and of themſelves (tho' at firſt put in Motion) move in their reſpective Orbits, which are *Curve-Lines* returning into themſelves, but are kept in them by ſome attractive Force, which if once ſuſpended, they would for ever run out in right Lines, and conſequently the Motions of theſe great Bodies in their Orbits, do abſolutely depend upon this attractive Force, whenceſoever it ariſes.

Corol. 3. Again, hence it follows, that neither Motion nor Reſt (I mean not one of them particularly) is eſſential to Matter, *i. e.* it will be ſtill Matter, in whichſoever of theſe States it be, and is indeed indifferent to both, or equally ſuſceptible of either.

LAW

The Second: A Body which moves deſcribes, or tends to deſcribe a ſtraight Line.

The Third: A Body that moves by the Force of divers Impreſſions towards different Places, but

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LAW II.

The Changes made in the Motions of Bodies are always proportional to the impreſs'd moving Force, and are produced in the ſame Direction with that of the moving Force.

Effects are always proportional to their *adequate* Cauſes; and if any Degree of Force produce any Degree of Motion, a double Degree of the ſame Force will produce a double Degree of Motion, and a triple a triple, and ſo on; and this Motion muſt proceed in the ſame Direction with that of the moving Force, ſince from this only the Motion ariſes: And becauſe by the former Law, Bodies in Motion cannot change their Direction of themſelves, ſo that unleſs ſome new Force alter its Courſe, the Body muſt proceed in the ſame Direction with that of the moving Force. And if the Body was before in Motion, the Motion ariſing from this impreſs'd Force, if in the ſame Direction, does ſo much encreaſe the former Motion, if it has a contrary Direction, it deſtroys a Part of the former Motion, equal to that which is impreſſed; when it has a Direction oblique to that of the former Motion, it is either added to, or ſubſtracted from the former Motion, according as the Motion ariſing from a Compoſition of theſe two is determined.

Coroll. Hence it is evident, that in the preſent Conſtitution of Things, there can be no perpetual Motion. By a perpetual Motion, I mean an uninterrupted Communication of the ſame Degree of Motion from one Part of Matter to another in a Circle: Not as Bodies put in Motion do for ever continue in the ſame, but in ſo far as they are reſiſted or ſtopp'd by other Bodies, but a Circulation of the ſame Quantity of Motion, ſo that it perpetually returns undiminiſhed upon the *firſt Mover.* For by this Law the Motion produced is but proportional to the generating Force; and all Motions on this Globe being performed in a reſiſting Fluid, *viz.* the Air, a conſiderable Quantity of the Motion muſt be ſpent in the Communication on this *Medium*; and conſequently it is impoſſible the ſame Quantity of Motion ſhould return undiminiſhed upon the *firſt Mover*, which is neceſſary toward but which are not diametrically oppoſite, complies with them all at once, as much as poſſible in Proportion to their Forces.

The Fourth: A Body that is moved, and in the End loſes its Motion, loſes it by Communication;

ward a perpetual Motion. Moreover, the Nature of material Organs is ſuch, that there is no avoiding a greater or leſſer Degree of Friction, tho' the Machine be formed according to the exacteſt Principles of *Geometry* and Mechanicks, there being no perfect Congruity or exact Smoothneſs in Nature; the Manner of the Coheſion of Bodies, the ſmall Proportion the ſolid Matter bears to the Vacuities in them, and the Nature of the conſtituent Particles of Bodies, not admitting the ſame. Beſides, how very imperfect our moſt finiſhed mechanick Performances are, a very ordinary Microſcope will eaſily diſcover. Now theſe Things muſt very conſiderably diminiſh the communicated Force, ſo that it is impoſſible there ſhould be a perpetual Motion, unleſs the communicated Force were ſo much greater than the generating Force, as to recompenſe the Diminution made therein by all theſe Cauſes; ſo that the impreſſed Motion may return undiminiſhed to the *firſt Mover*: But that being contrary to this Law, it is clear, that the Motion muſt continually decreaſe, till it at laſt ſtop; and conſequently there can be no perpetual Motion in the preſent State of Things.

LAW III.

Repulſe or Reaction is always equal to Impulſe or Action, or the Action of two Bodies upon one another, is always equal, but with a contrary Direction, i. e. *The ſame Force with which one Body ſtrikes upon another, is returned upon the firſt by that other; but theſe Forces are impreſſed with contrary Directions.*

Whatever preſſes or draws another, is as much preſs'd or drawn by that other: If one preſſes a Stone with his Finger, the Stone preſſes his Finger again. If a Horſe draw forward a Stone by a Rope, the Stone does equally draw back the Horſe; for the Rope being equally diſtended both Ways, acts upon both equally. If one ſtrike an Anvil with a Hammer, the Anvil ſtrikes the Hammer with equal Force. The Steel draws the Magnet as much as the nication; that is to ſay, one Body which ſtrikes againſt another, loſes of its Motion proportionally, as it cauſes Motion in the other. Let us conſider ſome Particulars for the Proof of the Effects of every Rule.

RULE I.

A Body which is moved continues in Motion until ſome external and particular Cauſe determine it to reſt.

I demonſtrate it thus: A Body paſſes from Motion to reſt of itſelf, or the Author of Nature makes it paſs without the Encounter of an external and particular Cauſe; or the Body continues to move, as the Rule ſays: But, a Body

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the Magnet does the Steel, as is evident, by making both ſwim in Water: So in pulling a Barge to Land by a Rope, the Barge pulls the Bank as much as the Bank does the Barge; and in the Deſcent of heavy Bodies, the Stone attracts the Earth as much as the Earth does the Stone, *i.e.* the Earth gravitates toward the Stone, as much as the Stone does toward the Earth. And the Motions produced by both theſe Gravitations are equal in both, only the Stone is altogether inconſiderable, in reſpect of the Bulk of the Earth; and conſequently the Velocity of the Earth's Motion toward the Stone is inconſiderable, in reſpect of the Stone's Motion towards the Earth; and therefore the Motion of the Earth toward the Stone is inſenſible. And univerſally in all the Actions of Bodies, if a Body act on another, and change its Motion any Manner of Way, that other will make the ſame Change in the Motion of this Body, with a contrary Direction; ſo that by theſe Actions there are made equal Changes, not of the Velocities, but of the Motion; for the Changes made on the Velocities in contrary Directions, are in a reciprocal Proportion to the Quantity of Matter contained in the Bodies. *Vide Cheyne's Philoſ. Principles,* p. 7, &c.

Body that moves does not paſs from Motion to Reſt of itſelf. Why, and how can it paſs of itſelf from one State to another? It has no Power; it is nothing but a Portion of Extenſion, which neither has any Force, nor any Intereſt to repoſe itſelf more than to move itſelf, by the firſt Principle.

2. The Author of Nature never makes it paſs from one State to another, from a State of Motion to that of Reſt, without the Action of a particular Cauſe; even as he never makes it without that paſs from Reſt to Motion, nor from one Figure to another: But he preſerves the Body in the ſame State, till ſome particular Cauſe determine him to preſerve it in another. As he is a ſimple and unchangeable Being, he has made, and obſerves Simple, conſtant and uniform Laws, which bear upon them the Impreſſion of his Attributes: Therefore a Body which is moved continues to move, until ſome external and particular Cauſe determine it to reſt.

Hence, when a Body has received Motion, it may preſerve it without the Aid of a particular Cauſe. Without this Aid, a Stone thrown into the Air aſcends, till having inſenſibly loſt its Force by the ſucceſſive Encounter of divers Parts of Air, it falls again at laſt by Virtue of its Weight.

Ariſt. Would a Ball then ſhot toward the *Eaſt*, or toward the *Weſt*, move continually, if it ſhould meet with no Obſtacle toward the ſame Place, with the ſame Direction, and the ſame Velocity?

Eud. I don't doubt it. A Stone thrown perpendicularly, would continue in an uniform Motion to reach the *Zenith*. The Indifferency of Bodies is alike as to Reſt, Motion, Direction, and Velocity. They have no more that Byaſs to Reſt, or to the Center of the Earth, which the antient Philoſophers found in them, or imputed to them *.

Ariſt. But if the moved Body never ceaſed to move, would not its Motion be infinite?

Eud. It would not properly be infinite, ſince it would continually double its Velocity.

Ariſt. I ſee it; notwithſtanding *Ariſtotle*'s Authority, you will not allow that Bodies which are moved, owe the Preſervation of their Motion to the Impreſſion of the Air.

Eudox. Becauſe the Air is an Obſtacle to Motion, therefore it muſt be far from continuing it. Put a Pendulum into the Receiver of an Air Pump, and pump out the Air; the Vibrations of the Pendulum will thereby acquire a greater Velocity.

Ariſt. I am wholly of your Opinion as to the firſt Rule.

Eud. Let us paſs to the ſecond.

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* See the Notes on CONVERSAT. XVII. Vol. I.

RULE II.

Every Body that moves, deſcribes, or tends to deſcribe a ſtraight Line.

I demonſtrate it thus: A Body, which of itſelf preſerves the ſame Direction as much as poſſible, deſcribes, or tends to deſcribe a ſtraight Line: For to deſcribe a crooked Line is to change the Direction; it is ſucceſſively to regard divers Points of the World: But every Body that is moved, preſerves of itſelf the ſame Direction as much as it can; ſince of itſelf it cannot change it, and is indifferent either to ſuch or ſuch a Direction, by the third Principle, having no Force, no Intereſt, no Byaſs to carry it, rather toward the *Eaſt* than toward the *Weſt*, toward the *South* than toward the *North.* Therefore every Body that is moved deſcribes, or tends to deſcribe a ſtraight Line. Accordingly every Body that is forced to deſcribe a Curve Line, runs off in a ſtraight Line wherever it is at Liberty.

Hence, If the moved Body deſcribe preciſely, a Square Figure, it muſt in its Way encounter with four Obſtacles. Of itſelf it would always follow a ſtraight Line; it is altogether a Stranger to Turnings.

2. What is it that cauſes circular Motion? A Continuance of Obſtacles; for a Body that is moved, always endeavours to follow a ſtraight

Line; nevertheleſs it leaves it every Moment. What obliges it to that, if it be not a Continuation of Obſtacles?

3. A Body moved circularly endeavours to remove from the Center of its Motion. In a Word, it tends to deſcribe a ſtraight Line; and this Effort removes it from the Center. Make a Stone move round your Hand in a Sling; and your Hand, which is the Center of Motion, feels the Effort which the Stone makes in order to remove. If you make a Veſſel full of Water move round in a Sling, the Water is not diffus'd; why? The Effort, which it makes to remove from the Hand, gives it a Direction which removes it from the Brim, and fixes it to the Bottom of the Veſſel.

4. A Body that makes an Effort to remove from the Center of its circular Motion, endeavours to go off in a Tangent (*ab*) *Fig.* 10. As the Points of the Circle are ſo many Beginnings of Tangents, or of ſtraight Lines contained in ſome Sort upon the Circle, and which only touch it in one Point, the Body that moves round receives in every Point a Direction to follow the Tangent; and you may ſee it follow the ſame effectually, whenever it is at Liberty; it follows it whenever it gets out of the Sling.

5. When ſeveral Bodies are carried rapidly at once round a common Center, thoſe which are fitteſt for Motion, and have moſt Force, make the greateſt Effort to remove from the Center.

V. 1. p. 98.

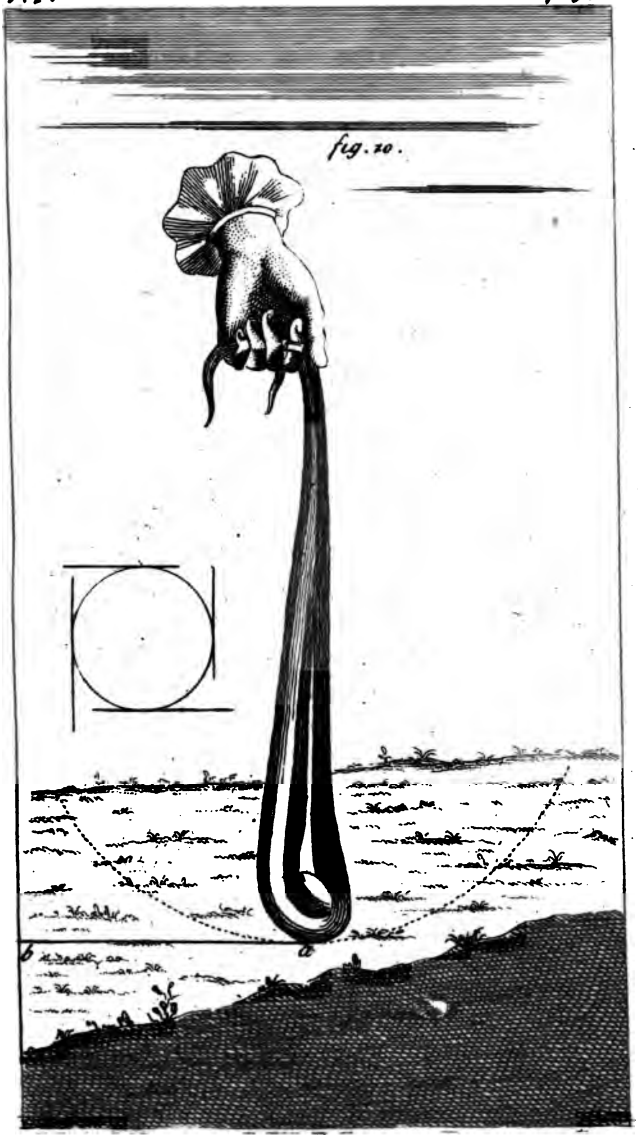
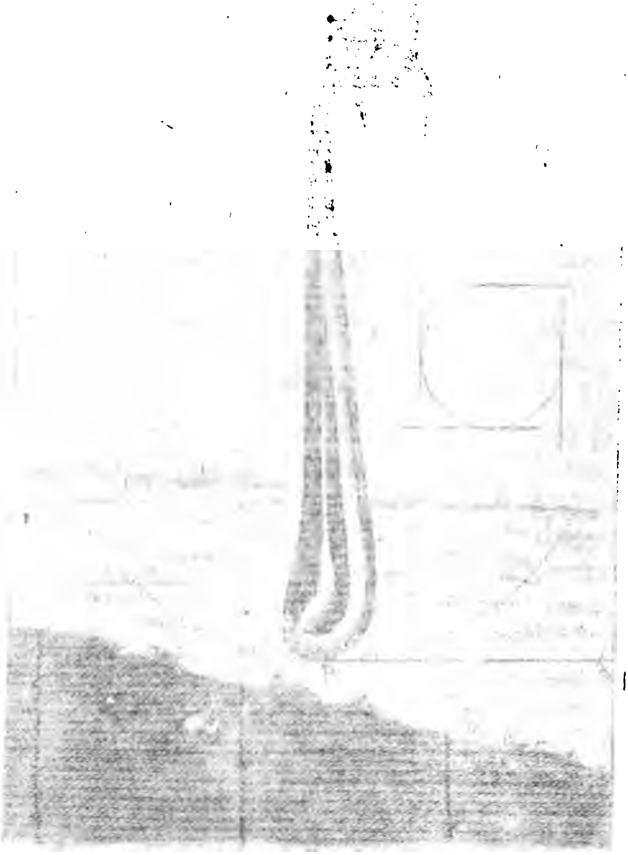


fig. 10.



Center. The Effort of a Body in Motion anſwers to its Force, it makes all it can.

6. Upon this Suppoſition, thoſe Bodies which have moſt Force, drive back the others toward the Center. The ſtronger cannot remove, without taking the Place of the weaker: For there is no Appearance of Vacuities capable of receiving the ſtronger; and the weaker cannot yield their Places without withdrawing into thoſe which the ſtronger have left free toward the Center. If you ſhould agitate in a circular Manner the Corn with the Chaff in a Sieve, the Corn carried toward the Circumference forces the Chaff which is weakeſt, to unite in the Center.

Finally, Should a Body that moves round a Center be a ſolid Body, its Parts move ſo much the more ſwiftly, the farther diſtant they are from the Center. In a Wheel, *e. g.* the farther diſtant the Parts of the Spokes are from the Axle-tree, the more Velocity they have, ſince in the ſame time they make ſo much the more Way.

Ariſt. The Conſequences of the ſecond Rule are evident.

Eud. Thoſe of the third will be no leſs ſo.

RULE III.

A Body that is moved by the Efficacy of different Impreſſions toward different Points, or which receives divers Directions, complies with them all, as much as poſſible, in Proportion to their Forces.

I demonſtrate it thus: 1. It complies with all the Impreſſions, ſince it is indifferent to them all, and can of itſelf refuſe none of them. 2. It complies, I ſay, with all, in Proportion to their Forces; for a greater Force muſt prevail beyond a leſs proportionally, as the one is greater, and the other leſs.

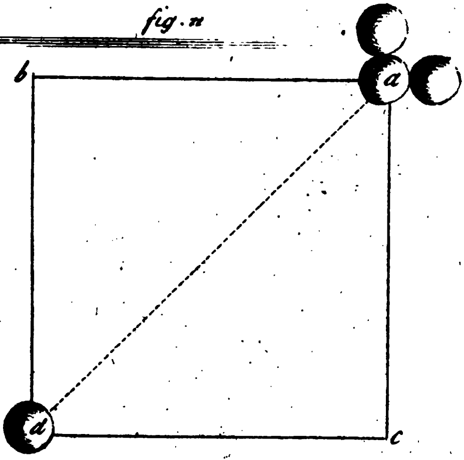
Hence, Suppoſe you ſtand upright in a Boat, let it hit againſt the Bank, it recoils; and while it recoils, if you are not on your Guard, you will fall all along: Why?

Ariſt. I ſee the Reaſon of it. While the Boat recoils, the upper Part of my Body preſerves its firſt Direction toward the Bank: My Feet, being fixed to the Boat, receive a contrary Direction to recoil immediately from the Boat itſelf. My Body complies with two Directions; the Feet recoil, the Head advances; the middle of my Body being ſupported by nothing, falls; and thus I come to be laid all along.

Eud. You riſe again with ſome Applauſe. Then being placed upon a Cylinder endeavour

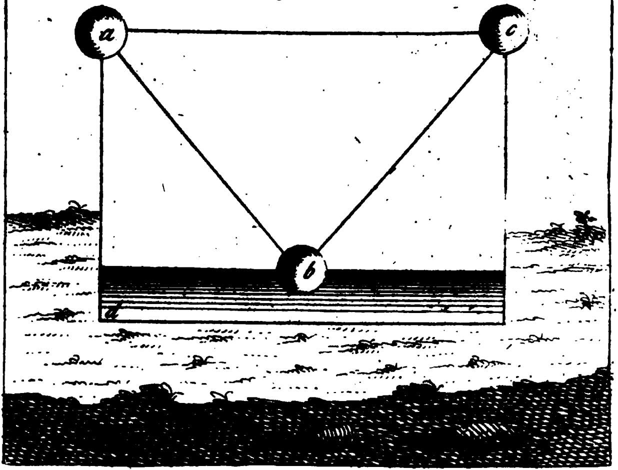
V. 1. P. 101.

fig. 11



P. 107.

fig. 12.



to leap forward. What happens upon this Attempt?

Ariſt. The ſame Effect; a merry Fall. I give the upper Part of my Body a Direction to go forward, and to my Feet to move backward. My Feet being ſupported by a moveable Cylinder, follow their Direction, and recoil; my Head follows its Direction, and goes forward. The middle of my Body finds itſelf without any Support, and I fall with my Noſe upon the Ground. This gives me ſome Confuſion, and in ſpite of all your Philoſophic Gravity you do nothing but laugh at it.

Eudox. You are too well acquainted with the Rules of Motion to expoſe yourſelf to give this little Scene: But let us ſeriouſly examine the principal Conſequences of the third Rule. I ſuppoſe that a Body receives two Impreſſions toward different Points that are not diametrically oppoſite, or two Directions, *Fig.* 11. the one *(a b)* horizontal or parallel to the Horizon and the other *(a c)* perpendicular to the Horizon. What Courſe will it take?

Ariſt. A compound oblique and middle Direction will be made up of theſe two Directions, namely, *(a d)* which approaches the horizontal and perpendicular Directions, more or leſs, in Proportion to the Force, both of the one and the other, ſince it ought to yield both to the one and the other in Proportion to their Forces, by the third Rule.

Eud. And as an oblique Direction is formed of two Directions, the one perpendicular, and another parallel, we may ſay, that the oblique Motion has two Directions, one parallel, and the other perpendicular. In a Word, it brings the Body nearer to divers Points of two Lines, the one parallel, the other perpendicular, which would be the two Sides of a Parallelogram *e g*, of an exact Square, or of an oblong Parallelogram. Nothing more is neceſſary to underſtand how the Wind makes a Mill go round.

Ariſt. This is a thing which appears at firſt eaſy to conceive, but nevertheleſs becomes difficult when one conſiders it.

Eud. This is the Way I conceive it. The Axis of the Mill is in the Direction of the Wind; the Surface of the Sails making with the Axis, to which they are faſtned, an Angle of 55 Degrees, and in a Situation oblique to the Wind. The Wind which blows obliquely upon the Surface of the Sails, has two Directions of oblique Motion, the one parallel, and the other perpendicular to the Surface of the Sails. By the parallel Direction the Wind does not puſh the Surface of the Sails; for a Direction parallel to a Body does not convey to it the Effort of the Body moved. By the perpendicular Direction the Wind gives an Impreſſion to the Surface of the Sails, in order to drive them backward by an oblique and middle Line, between the Axis and a Line perpendicular to it. The Surface of every Sail receives then two Directions from the Wind, one perpendicular to the Axis, and another parallel, which brings it nearer to the Axis. The Surface cannot follow the parallel Direction without breaking: It may freely yield to the perpendicular Direction without Danger, and it does ſo. But as it is attach'd to the Axis, it is oblig'd to change from a Perpendicular every Moment, which it does. Changing from a ſtraight Line every Moment, it deſcribes a Curve and circular Line, and makes the Axis turn round with it ſo much the more eaſily, becauſe every Surface anſwering to another diſpoſed obliquely, and a contrary Way, the Force which makes one aſcend, helps the other to deſcend; the Force which makes one deſcend, helps another to aſcend: So that the Situation of every Surface conſpires to the ſame circular Motion. Hence the Mechaniſm of the Mill.

Would you have an Explanation of it more ſhort and ſimple? The Air being violently driven againſt the oblique Wings of the Mill, endeavouring to dilate itſelf every Way by Virtue of its Spring, puſh the Sails both toward the Mill, and toward the Parts whither they are carried. The Sails cannot approach nearer to the Mill without breaking: They can, without breaking, follow the other Impreſſion; they follow it, and the Mill goes round: But ſuppoſe the horizontal and perpendicular Directions be always equal, what Species of oblique and middle Line will the moved Body deſcribe?

Ariſt. The Diagonal of a Square; becauſe in this Suppoſition it ought equally to approach the horizontal and perpendicular Lines, which make two Sides of a Square; and it cannot approach them equally but by the Diagonal, drawn from one Angle to the Angle diametrically oppoſite. Suppoſe a Billiard Ball receive in this Corner of your Cloſet two equal Impreſſions, one to go along the Wall on the Right, and another to go along the Wall on the Left; this Ball taking a middle Courſe will run into that Corner directly over againſt us, that it may equally yield to the two Impreſſions.

Eud. But if there be any Inequality in the two Impreſſions, or in the two Directions of a Body, ſo that the one diminiſhes every Moment, and the other increaſes proportionally; what happens?

Ariſt. The Body moved deſcribes a Curve Line, that is a Parabola: For it deſcribes a Line which changes its Direction every Moment, removing always from that which diminiſhes; ſince the prevailing Direction forcing it from the other, carries it every Moment towards a new Point: Now a Line of this Kind is a Curve Line, a Parabola, *&c.*

Eud. According to this Principle a Canon Bullet deſcribes a Parabolical Line. It receives two Impreſſions, two Directions, the one horizontal or Parallel to the Surface of the Earth, the other perpendicular. That proceeds from the Gun-powder, and this from the Gravity. The firſt is diminiſhed every Moment by the Reſiſtance of the Air, and the other increaſes by the repeated Efforts of the Gravity. Increaſing every Moment it gives the Bullet new Directions, carries it toward different Points of the Earth, and brings it nearer to the Perpendicular. The Line made up of thoſe Changes of Direction is a crooked Parabolic Line. The ſame Line is deſcribed by the Ball of a Fuzee, for the ſame Reaſon. Would you hit a Mark at the End of the Reach of a Canon or Fuzee? Fix your Eye a little higher: But let me have the Pleaſure of perplexing you with ſome Problems.

The firſt Problem. Why, I pray, does a Ball, while a Veſſel ſails full before the Wind, fall from the Scuttle to the Foot of the Maſt in a Curve Line, obſerved by thoſe who look from the Shore?

Ariſt. The Ball has two unequal Directions, one horizontal, or parallel to the Horizon, which proceeds from the Veſſel, and another perpendicular and ſtronger, which proceeds from the Gravity. The Ball yielding to both in Proportion to their Forces, advances with the Veſſel in a Curve Line, which lays it down at the Foot of the Maſt.

Eud. 2. *Problem.* A Ball thrown perpendicularly from the Foot of the Maſt, falls a-again at the Foot of the Maſt, tho' the Veſſel be carried forward with Rapidity; why?

Ariſt. For the ſame Reaſon. The Ball obeying its two Impreſſions proportionally to its two unequal Directions, is carried again by a Curve Line to the Foot of the Maſt.

Eud. 3. *Problem.* An Horſeman riding full Speed throws an Orange into the Air; the Orange falls again into his Hand; why?

Ariſt. For the ſame Reaſon ſtill. The Orange following the third Rule, yields to its two unequal Impreſſions agreeably to the Inequality of their Forces, and by a Curve Line meets the Hand again which threw it.

Eud. 4. *Problem.* Now I will give you a more difficult Problem. Upon a Plane, the Plane of a Billiard-Table for Example, with the Edge of my Hand, and a ſmart Blow, I ſtrike a Billiard Ball about the Middle of its Diameter; the Billiard Ball being ſtruck runs off from under the Hand, and retires in a right Line toward the Hand which ſtruck it: You would imagine it purpoſed to take Vengeance for the Blow it had received.

Ariſt. The Ball being ſtruck by an Hand which ſlides upon its Circumference, and in a Place which does not carry it immediately upon the Plane, receives two Motions at a time, the one ſtraight, and the other circular, and yields to both. By the ſtraight Motion it removes; but this Motion is loſt by the Encounter and Reſiſtance of the Air, which it muſt divide in order to advance. The circular Motion, which does not meet with the ſame Obſtacle, ſubſiſts a longer time, and being ſeconded by the Reaction of the Air, puſh'd by the ſtraight Motion, it brings back the Ball towards the Hand; while the Ball, wholly indifferent, either to Motion or Reſt, thinks nothing of revenging the Blow it has received.

Eud. When one underſtands what has been ſaid, it is eaſy to comprehend the Motions of Reflexion and Refraction.

I throw a Billiard Ball obliquely upon a Plane: After the Stroke of the Plane it aſcends and paſſes to the other Side by a reflected Motion. Why?

Ariſt. The oblique Motion of the Billiard Ball *(a b) Fig.* 12. is compounded of two Directions, the one parallel *(a c)* and the other *(a d)* perpendicular to the Plane. The Plane being impenetrable to the Billiard Ball, and directly oppoſed to the perpendicular Direction downward, changes it into a perpendicular Direction upward: But the parallel Direction remains; as it is parallel to the Plane, it does not encounter the Plane, and the Plane changes it in no Sort. What then muſt the Billiard Ball do after encountering the Plane? Take a middle Courſe *(b c)* to yield to thoſe two Directions, according to their Forces. It takes it without fail; and this is the Motion of Reflexion.

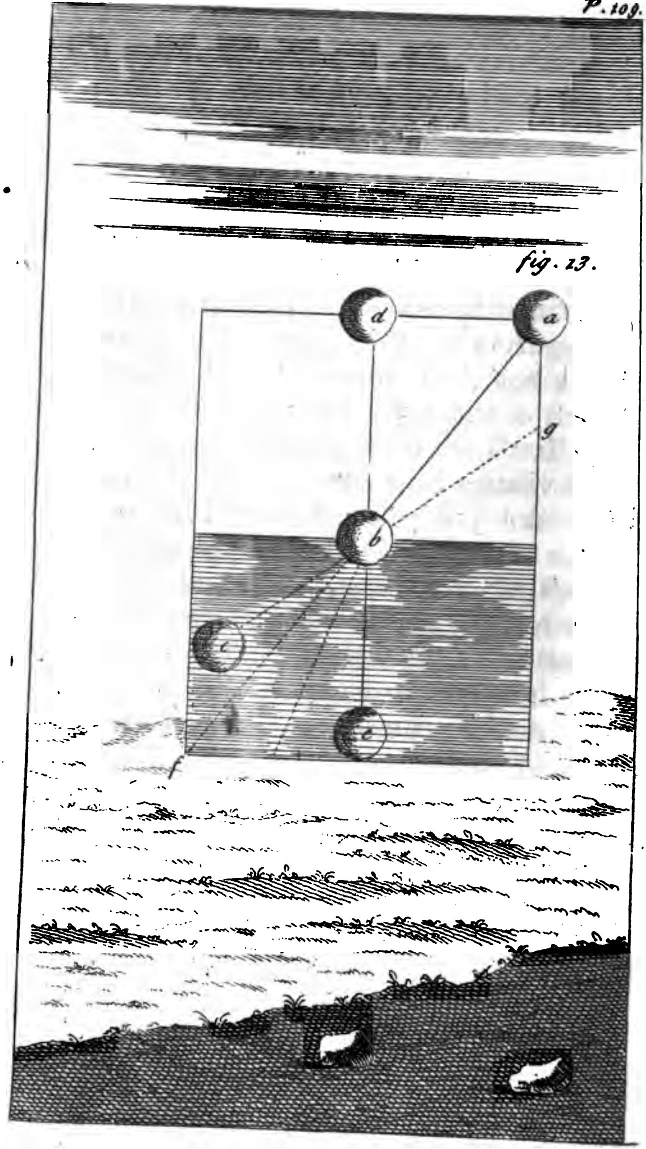
Eud. This Motion of Reflexion makes an Angle with a Plane, which they call an Angle of Reflexion; as the Motion by which the Plane is ſtruck makes with it an Angle, which they call the Angle of Incidence. But ought the Angle of Reflexion to be equal to the Angle of Incidence or not?

Ariſt. If in the Fall and the Stroke the Body loſes nothing of its Force; and that none of the Directions be diminiſh'd, the Angles ought to be equal; ſince in the Fall, and after the Stroke, the Body moved ought to deſcribe a Line equally diſtant from the Parallel and Perpendicular, in order to yield equally to equal Forces and Directions: But if it loſe of its Force; if the perpendicular Direction be diminiſhed, and diminiſhed more than the Parallel, as it happens in ſenſible Bodies, the Angle of Reflexion ought to be leſs, ſince the Body moved ought to yield more to the parallel Direction than to the Perpendicular, which is become weaker.

Eud. I think you ought to know at preſent the Reaſon of thoſe Undulations on the Water called Ducks and Drakes, as well at leaſt as you knew how to make them, when you was younger.

Ariſt. The ſmall flat and round Stone, which rapidly and obliquely grazes upon and ſkips along the Surface of the Water, has its two Directions, the one parallel and much ſtronger, the other perpendicular downward, and much

fig. 23.



much weaker. The Plane of the Water, by its Reſiſtance, immediately changes the perpendicular Direction downwards, into a perpendicular Direction upwards; and the Stone is reflected, according to the Rule, by a mean and oblique Line. Then the Gravity in its Turn changes the perpendicular Direction upward, into a perpendicular Direction downward, while the parallel Direction ſtill continues; and the Stone, obedient to the third Rule, proceeds again by an oblique Line to graze upon the Surface of the Water. This Diverſion continues for the ſame Reaſon, until the Stone having loſt its Motion, is ſunk by Virtue of its Gravity. It is by the Reaſon of Ducks and Drakes that a Cannon-Ball, after having grazed upon the Surface of the Sea, is ſometimes reflected ſo as to cauſe Death, even upon the Deck of a Ship.

Eud. But I ſuppoſe that a Body, which is moved *(a, b, c) Fig.* 13. paſſes obliquely from one *Medium* into another, from Air, for Example, into Water, or from Water into Air. In the Point of paſſing *(b)* the Line which it deſcribes is broken; it turns aſide a little, ſometimes removing from the perpendicular Line *(d e)*, or the Line which paſſes perpendicularly through the two *Mediums*, and ſometimes approaching to the ſaid Line; and theſe are Refractions. How do they happen?

Ariſt. The Body, which paſſes obliquely from one *Medium* into another, has its two

Directions, one parallel to the Surface of the *Medium*, into which it paſſes, and the other perpendicular. When it reaches the Surface of a *Medium* that reſiſts more than that from which it comes, as it happens when a Ball paſſes from Air into Water, it finds a greater Reſiſtance at the perpendicular Direction than at the Parallel; the Exceſs of Reſiſtance diminiſhes the perpendicular Direction, while no Exceſs of Reſiſtance diminiſhes the Parallel: Therefore after the Diminution of the perpendicular Direction, the Body moved ought to yield leſs to it, and more to the Parallel. It cannot do ſo, without removing a little from the perpendicular Line which cuts the two *Mediums*: It removes from it; and this is one Species of Refraction. When it reaches a *Medium* that reſiſts leſs, it finds more Reſiſtance at the parallel Direction, than at the Perpendicular. After the Diminution of the parallel Direction, the Body moved ought to yield leſs to it, and more to the other: It cannot do ſo without approaching to the Line perpendicular to the two *Mediums*; and this is another Sort of Refraction. Hence the Ball *(a b c)* which paſſes obliquely from Air into Water, removes from the Perpendicular *(d e)*, loſing its Tendency to the ſame Point *(f)*. If it paſs from Water into Air, it approaches to the Perpendicular *(d e)*, ceaſing to aim at the ſame Point *(g)*. If you deſign to ſhoot a Fiſh in the Water, you muſt fix your Eye a little lower:

er. The Refraction will make the Ball aſcend, and carry it into the Body of the Fiſh.

Eud. But finally the Motion of Refraction, as well as that of Reflection, curve Motion as well as ſtrait, ſimple and Compound are loſt. How does that happen? Why, thus, as I imagine.

RULE IV.

Motion that is loſt, is loſt by Communication.

Motion, I ſay, is loſt by Communication; or Reſiſtance deſtroys it. But Reſiſtance does not deſtroy it: For if Reſiſtance did deſtroy it, ſince the Stars diffuſe their Light every where, and all, or almoſt all Bodies act one againſt another, and continually reſiſt each other, in a ſhort Time all Motion would be deſtroyed, both in the ſubtile Matter and in the Univerſe; all Bodies ſhould quickly be frozen, an unhappy Languor would ſpread itſelf over all Nature, and the Univerſe would be reduced to a frightful Chaos.

You will ſay perhaps that the Spring, or that which reſtores to compreſſed Bodies their former Figure, reſtores alſo the Motion which they have loſt. But ought not the Spring itſelf to be annihilated? For Body being only a Portion of Matter, is perfectly indifferent to all imaginable Figures. Therefore if after Compreſſion it reſume its former Figure, an external Cauſe muſt reſtore it by ſtriking againſt it. This external Cauſe which ſtrikes it, is a Body. This Body is imperceptible. Therefore it is the Air, or ſome finer Matter, the ſubtile Matter. It is not the Air. The Air has its Spring, which depends upon an external Cauſe. Therefore it is the ſubtile Matter. But the ſubtile Matter finding Reſiſtance both in elaſtic Bodies, and in all that it encounters, would loſe its Force. Therefore the Cauſe of the Spring, and conſequently the Spring itſelf ought, as I think, to be annihilated. Therefore Motion is loſt by Communication. Thus we every Day ſee Bodies continue to move more or leſs in Proportion as they communicate more of their Force,

Ariſt. If Motion is loſt after that Manner, it is found in one Body proportionally as it is loſt in another. This ſeems plain.

Eud. Hence the Knowledge and natural Explanation of a Number of curious Facts.

Ariſt. Let us attempt to explain them according to your Principles.

Eud. 1. One is more fatigued by walking upon moving Sand, than upon dry Ground, or upon Pavement itſelf. Why?

Ariſt. One communicates much more Motion to the moving Sand becauſe it yields, and becauſe the greateſt Part of the Grains of Sand receive their particular Motion, beſide the common Motion. The more one communicates, the more one loſes; the more is loſt, the more one is exhauſted; and the more one is exhauſted, the more one is fatigued.

Eud. 2. A Cannon-Bullet ought then to be ſooner ſtopp'd in the Air, than in Water.

Ariſt. Quite otherwiſe; it ought to ſtop, and does ſtop ſooner in Water; the Water yields, and is divided indeed, but with more Difficulty; it muſt therefore give it more Force; the Bullet does give it more Force; and the more it gives, the more it loſes.

Eud. 3. If the Bullet paſs through the Air over a very large River, or a Pond, it falls down much ſooner. What precipitates its Fall?

Ariſt. It is an Exceſs of Reſiſtance in an Air more filled with Vapours, and more denſe, which is divided with great Difficulty. The Bullet, in order to divide it, imparts more Motion; in Proportion as it imparts more, it loſes more; proportionally as it loſes more, it finds an End of it ſooner.

Eud. 4. Suppoſe the Bullet encounter a Rampart of Earth, a Brick Wall, or a Sack of Wool, the Motion is ſooner deadened than by the Stroke of a very hard and thick Wall.

Ariſt. In the Earth, Wool and Brick the Parts are ſufficiently flexible, they give Place, bend, and are looſened pretty eaſily, to receive from the Bullet each their Quantity of proper Motion. Theſe Quantities of proper Motion quickly equal the common Motion of the Bullet; and this is ſo much loſs to it. The Bullet having in a ſhort Time loſt its Motion, is quickly deadened, and remains at Reſt in the Earth, Brick or Wool. But ſhould it encounter a thick Wall of very hard Stones, the Parts of theſe Stones are not ſufficiently flexible, do not yield, nor bend, nor are looſened with Eaſe enough, ſo as each may receive its Quantity of particular Motion; they only receive a common Motion which does not at all equal that of the Bullet; and the Bullet recoils with that Force, which is left it.

Eud. 5. But the Bullet, which would be quickly deadened in the Brick, makes a Pannel fall from a Wall more hard and ſolid.

Ariſt. It does this, becauſe it ought ſo to do according to the fourth Rule. In the Brick the Motion becomes peculiar in ſome Sort to the imperceptible Parts. From the imperceptible Parts of the Brick it paſſes into thoſe of the Air and ſubtile Matter; and the whole Effort of the Bullet is, as it were, annihilated. But in the Pannel of a much harder Wall, the Motion of the Bullet does not become proper to the imperceptible Parts; it is almoſt wholly employed to diſplace the Pannel of the Wall. It does diſplace it, and makes a free Paſſage for the Enemy.

Eud. 6. The Cannon-Ball does not perplex you. But an Arrow, which preſents its Point to the Reſiſtance of the Air before it goes a great Way; whilſt another Arrow, which preſents its Side, falls down again almoſt immediately.

diately. Theſe two Arrows may give you more Uneaſineſs than the Bullet.

Ariſt. Not at all. The Arrow, which preſents only its Point to the Air, goes a long Way, becauſe encountering but with little Air every Moment it communicates and loſes little of its Motion. The other, which preſents a much larger Surface, quickly falls again, becauſe meeting with much more Air every Moment, it communicates and loſes much more of its Force.

For the ſame Reaſon a Beam, whoſe Extremity cuts the Air, is more eaſily carried; and a Boat, which preſents its Side to the anterior Air, is ſtopped with leſs Effort.

Eud. Hence the larger Surface a Body has in Regard of its Maſs, the more of its Force it loſes every Moment. As it ſtrikes againſt more Parts of the *Medium* which it muſt cut through, it gives equal Quantities of Motion to more determined Parts; and the more it gives, the more it loſes. But the ſmaller Bodies are, the larger Surface they have in Regard of their Maſs. For divide a Globe into two Hemiſpheres, before the Diviſion the two Hemiſpheres had only the Circumference of the Globe for their Surface, but after the Diviſion they have for Surface, both this Circumference, and likewiſe two Planes: Therefore Bodies, the ſmaller they are, loſe the more of their Force, *cæteris paribus.*

This being granted, I put into two equal Fuſees the ſame Load of Powder, ten Shot into one, and into the other a Bullet whoſe Weight equals the ten Shot. Will the ten Shot go as far as the Ball?

Ariſt. No. The ten Shot being ſmaller, each in Particular, than the Ball, they have more Surface in Regard of their Maſs; having more Surface, they will encounter more Obſtacles; encountering more Obſtacles, they will communicate more Force; communicating more Force, they will loſe more; loſing more Force, they will make leſs Way: Therefore they will not go ſo far as the Bullet.

Eud. But inſtead of Fuſees, Bullet and Shot, I ſuppoſe two *Jets d'Eau*. In one of them the Water runs off in Threads through a Number of ſmall Pipes, and falls down again in Rain; in the other an equal Quantity of Water ſprings up by the ſame Paſſage in Form of a Cylinder. Which of the two ſprings higheſt?

Ariſt. The laſt; ſince having leſs Surface in Proportion to its Maſs, it communicates every Moment, and loſes leſs of its Force.

Eud. After this it is eaſy to comprehend why rugged Bodies move with greater Difficulty than ſuch as are poliſhed; becauſe the firſt having more Surface on Account of their Inequalities, meet with more Obſtacles, and communicate more of their Motion. But finally,

nally, whence proceeds that Facility in ſpherical Bodies to turn round upon their Center?

Ariſt. Finding no great Impediment to their circular Motion, they communicate but little of it. Hence a Whirligigg and a Top keep theirs a long Time; and turning about upon their Center, ſeem to ſleep calmly, without any Fear of loſing their Forces.

Eud. Here then, in a Word, are the four Rules of Motion, which all Bodies follow, as it were, with Emulation.

Rule I. A Body that is moved ought to continue in Motion, until ſome external and particular Cauſe determine it to reſt.

Rule II. A Body that is moved deſcribes, or tends to deſcribe, a ſtrait Line.

Rule III. A Body carried by different Impreſſions towards different Points, or which has divers Determinations, yields to them all in Proportion to their Forces.

Rule IV. Motion that is loſt, is loſt by Communication.

All theſe Rules are equally obſerved both in hard, elaſtic and ſoft Bodies.

Ariſt. But what is the Cauſe of the Hardneſs, Elaſticity, and Softneſs of Bodies?

Eud. This is a difficult Subject which deſerves to be thought on before one pretend to diſcourſe of it.

CONVERSATION IX.

Upon the Hardneſs, Elaſticity and Softneſs of Bodies.

Eud. WELL, *Ariſtus*, what is the Hardneſs ‡ of Bodies according to your Judgment?

Ariſt. It is the Reſiſtance of Bodies to the Diviſion of their Parts. But whence this Reſiſtance

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‡ All Bodies that are perceived by our Senſes, conſiſt of very ſmall Parts, no one of which is indiviſible of itſelf; but all of them are in Reſpect to us: For all the Diviſion we can make is only a Separation of Parts. When a great Force is required to make ſuch a Diviſion, a Body is ſaid to be *hard*.

If the Parts yield more eaſily, and fall in by being preſſed, ſuch a Body is ſaid to be *ſoft*.

But this great and leſſer Force in the common Signification, determine nothing; for a Body that is hard in Reſpect to one Man, ſeems ſoft to another.

Defin. 1. A Body is ſaid to be *hard* in a Philoſophical Senſe, *when its Parts do not alter their Situation with Regard to one another upon any Force impreſſed.*

Defin. 2. A Body is ſaid to be *ſoft*, in a Philoſophical Senſe, *when its Parts yield inwards, and ſlip in upon one another, even though it may require a Blow with a Hammer to do it.*

Defin. 3. A Body whoſe Parts yield to any Impreſſion, and by yielding are eaſily moved, in Reſpect to each other, is called a *Fluid*.

All theſe Things depend upon the Coheſion of Parts, the cloſer that Coheſion is, the nearer a Body approaches to perfect Hardneſs.

But

ſiſtance proceeds, and what occaſions the Hardneſs of Bodies, I acknowledge I do not eaſily underſtand.

Eud.

But the Hardneſs of the ſmalleſt Parts does not differ from their Solidity, it is an eſſential Property of a Body, which is no more to be explained, than why a Body is extended, or a Mind thinks.

It is uncertain whether all Bodies conſiſt of Parts that are equal and alike: And there are alſo ſeveral Things very difficult in Relation to the Cauſe of the Coheſion of the ſmall Parts of Bodies.

It is a particular Law of Coheſion, that all the Parts have an *attractive Force.*

Defin. 4. By the Word *Attraction* I underſtand, *that Property by which two Bodies tend towards each other, without external Force.*

But that *Attraction* is ſubject to theſe Laws; *that it is very great in the very Contact of the Parts; and that it ſuddenly decreaſes, inſomuch that it acts no more at the leaſt ſenſible Diſtance; nay, at a greater Diſtance it is changed into a* repellent Force, *by which the Particles fly from each other.*

We ſee that in all Liquors all the Parts attract one another, from the ſpherical Figure that the Drops always have; and alſo becauſe there is no Liquor whoſe Parts are not ſticking to one another, which is evidently true even in *Mercury* itſelf. Beſides, in all Liquids, two Drops, as ſoon as they touch one another ever ſo little, immediately run into one larger Drop. All which Things, as they alſo happen in liquified Metals, it follows, that the Parts of which they are compounded do attract one another, even when they are disjoined by the Motion of the Fire.

Theſe Appearances do not depend upon the Preſſure of the Air, becauſe they alſo happen where there is no Air; neither do they depend upon the Preſſure of any other Matter equally from all Sides; for though ſuch a Preſſure is able to keep the Drops to their ſpherical Figure, it can by do Means bring them to it at firſt.

Defin. 5. *Elaſticity of Bodies*, namely, that Property *whereby they return to their former Figure, when it has been altered by any Force: This is eaſily deduced from what has been ſaid:* For if a compact Body be dented in without the Parts falling into that Dent, the Body will return to its former Figure, from the mutual Attraction of its Parts.

Eud. Hear then my Sentiment upon that Head. Hard and ſenſible Bodies have their perceptible and imperceptible Parts. The firſt are compounded of the laſt. Both the one and the other have their Hardneſs; whence proceeds, at leaſt in Part, the Hardneſs of ſenſible Bodies.

1. Whence proceeds the Hardneſs of the imperceptible Parts? From the relative Reſt of their Particles, purpoſely preſerved by the general Cauſe, or the Will of God, until ſome foreign and particular Cauſe come with a certain Degree of Force to divide them. The Hardneſs of the imperceptible Parts proceeds from this Principle, or from their own Nature, or from the Preſſure of ſome ſubtile and fine Matter, which ſurrounds them Now it does not proceed from the Nature of the imperceptible

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Now leſt any one ſhould imagine, becauſe we do not give the Cauſe of the ſaid Attraction and Repulſion, that they muſt be looked upon as *occult Qualities*; We ſay here with Sir *Iſaac Newton*, "That we conſider thoſe Principles not as occult Qualities, which are ſuppoſed to ariſe from the ſpecifick Forms of Things; but as univerſal Laws of Nature, by which the Things themſelves are formed: For the Phænomena of Nature ſhew, that there are really ſuch Principles, though it has not been yet explained what their Cauſes are. To affirm that the ſeveral Species of Things have occult ſpecifick Qualities, by which they act with a certain Force, is juſt ſaying nothing. But from two or three Phænomena of Nature to deduce general Principles of Motion, and then explain in what Manner the Properties and Actions of all Things follow from thoſe Principles, would be a great Progreſs made in Philoſophy, though the Cauſes of thoſe Principles ſhould not yet be known". *Vide Graveſande's Elements*, B. I. c. 5.

perceptible Parts; one ſees no Hardneſs in their Idea, and the Particles yet more minute, of which they are compounded, are themſelves perfectly indifferent as to their remaining, or not, near one another. Neither does it proceed from a more ſubtile and fine Matter which ſurrounds them. For, in ſhort, it is probable that this ſubtile and fine Matter has its own Hardneſs: But whence ſhould it have it? We muſt run up to Infinity. Beſides, all the Particles of the imperceptible Parts, would, without any Difficulty, run horizontally upon one another, as one poliſhed Marble upon another. The Hardneſs then of the imperceptible Parts proceeds from the relative Reſt of their Particles, ſuch as I have ſaid. In ſhort, there can be no other Principle of Hardneſs, and without Hardneſs there can be no Univerſe.

2. Whence proceeds the Hardneſs of the ſenſible Parts? From the firm, ſolid and unequal Texture of the imperceptible Parts. The imperceptible Parts inchaſed after a Thouſand Manners, and crowded into one another, make the ſenſible Parts; the Hardneſs of the imperceptible Parts, inchaſed and intangled after this Faſhion, obſtruct their Diviſion: Hence the Hardneſs of the ſenſible Parts, compoſed of a Texture of imperceptible Parts.

3. Laſtly, the perceptible and hard Parts having divers Figures, and being interwoven with one another, cannot be divided without the breaking of an infinite Number of ſmall, imperceptible

perceptible and hard Parts. From the Concatenation of theſe ſenſible Parts, ſeconded by the fluid or ſubtile Matter, and Air which ſurround them, preſſing them on all Sides toward a common Center, proceeds the Hardneſs of ſenſible Bodies.

Ariſt. According to your Sentiment the Hardneſs of the imperceptible Parts proceeds immediately from the relative Reſt of their Particles, the Hardneſs of the ſenſible Parts from the Texture of the imperceptible, and the Hardneſs of entire Bodies from the Concatenation of the ſenſible Parts and Preſſure of the Fluid which ſurround them. This is to explain, after a probable Manner, a Thing difficult to comprehend; and this makes me impatient to know what you think of the Elaſticity of Bodies.

Eud. The Action of foreign Force, the Effort of the Hand for Example, bends a Plate of Steel, compreſſes a Foot-Ball, bends a Bow, &c. Should this Action ceaſe, the Bodies reſume of themſelves, as it were, their former Figure; and that which makes them reſume it as of themſelves, is what they call the Spring, or elaſtic Force. What then is the Elaſticity of Bodies? It is that which makes them reſume as of themſelves that Figure which ſome foreign Force had taken from them.

Ariſt. But the Figure which folded, compreſſed, and bended Bodies, ſeem to reſume of themſelves, do they really reſume it of themſelves?

Eud. No; for being of themſelves only a Portion of Extenſion, they are no leſs indifferent to ſuch or ſuch a Figure, than to ſuch or ſuch a Direction; they are neither for a ſquare Figure, nor for a round one; the Figure which Compreſſion gives them fits and accomodates them, as well as that which it takes away from them.

Ariſt. Therefore ſome external Cauſe muſt reſtore to them, and oblige them to reſume the Figure which they have loſt by the Preſſure. But what is this external Cauſe? The ſubtile Matter, without doubt.

Eud. It is the ſubtile Matter or the Air, as we have obſerved already. It is an imperceptible Body; it is, I ſay, a Body; for it is ſomething that ſtrikes, touches and modifies: And this Body is imperceptible; the Senſes do not perceive it. But it is not the Air, the Air itſelf has its own Spring, as Experience ſhews. In a Foot-Ball the Air is compreſſed an hundred Times more than in its natural State. It reſumes its former Figure, and it reſumes it only becauſe it is reſtored to it: For it has no Intereſt to reſume it, it is very indifferent to it. Therefore the ſubtile Matter is the external Cauſe which reſtores to compreſſed Bodies, that Figure which the Preſſure had taken from them. Not but the Air, which has its Spring, and which finds itſelf ſhut up in the contracted ed Pores of other Bodies bended or compreſſed, contributes immediately, by Virtue of its Spring, to reſtore them to their former Figure: But it is the ſubtile Matter which ſets this Spring a-going.

Ariſt. But how does ſubtile Matter reſtore to Bodies the Figure which they had loſt?

Eud. In Compreſſion the Parts are bowed, the Pores of the Concave Surface are contracted, and the Pores of the convex Surface are enlarged. The ſubtile Matter, which is in a violent Agitation, paſſing from the laſt into the firſt accelerates its Motion, to the End that what paſſes through the larges Pores, may paſs in equal Times through thoſe which are more ſtrait; this Acceleration of Motion opens and dilates the contracted Pores, both of the Air, if any be met with, and alſo of the Body which contains it. The contracted Pores cannot be dilated without the Contraction of the enlarged ones; thoſe cannot be dilated, nor theſe contracted, without the compreſſed Bodies being reſtored to their former State: Thus the ſubtile Matter reſtores them to their former Figure, much after the ſame Manner as the Humidity imbibed into an extended Rope, but ſomewhat crooked, makes it ſtrait; or as Water that is filtred in a compreſſed Sponge, does extend and reſtore it to its natural Situation.

The ſubtile Matter may contribute farther to re-eſtabliſh compreſſed and curved Bodies in their firſt State, by flowing from one Extremity to another; as the Air, which we cauſe to enter with ſome Effort into a flexible and crooked Pipe, makes it change its Figure, and ſtreightens it.

Ariſt. I conceive perfectly well, and approve your Sentiment. The Action of the ſubtile Matter, which runs with ſome Acceleration of Motion into the Pores contracted by Compreſſion, is the external Cauſe which makes the Spring play, or unbends it. But beſide the Action of the ſubtile Matter, muſt there not moreover be an internal Cauſe, or ſome particular Diſpoſition on the Part of the Body?

Eud. That the Body may be rendered elaſtic, there muſt be a certain Flexibility of Parts, a certain Stiffneſs or Hardneſs, and Pores neither too ſmall, nor too large. There muſt be 1. a certain Flexibility of Parts; otherwiſe the Body cannot be compreſſed, nor conſequently dilated. 2. A certain Stiffneſs or Hardneſs; without this the ſubtile Matter making new Paſſages for itſelf too freely, would neither open nor enlarge the contracted Pores. 3. Pores which are not too ſmall, to give Acceſs to the Action of the ſubtile Matter. 4. Laſtly, Pores which are not too large, leſt the ſubtile Matter paſs through without making any Effort to enlarge them.

Ariſt. Your Sentiment concerning Elaſticity is perfectly agreeable to the Idea which I had formed to my ſelf in reading *M. Deſcartes,* and *M. Robault*; and nothing, I think, is more happy for explaining the ſurprizing Effects of Elaſticity, and whatever relates to it.

Eud. Let us make a Trial of it. The Force of Elaſticity is acquired, augmented, diminiſhed and loſt. Whence proceed theſe Changes, which are to Philoſophers ſo many Species of Miracles of Nature?

Ariſt. 1. If the Pores, which were too large, are contracted, or thoſe which were too ſmall are enlarged, the ſubtile Matter begins to paſs with ſome Violence through the one and the other; its Action dilates and extends them; and thus you have ſome acquired Force of Elaſticity.

2. Let the contracted Pores be contracted yet more, or let the enlarged Pores be ſtill more enlarged, there paſſes more ſubtile Matter through the laſt, and it paſſes with a greater Effort through the firſt, and thus the Spring is augmented.

3. Are the Pores a little too much contracted, or too much enlarged? There paſſes too little ſubtile Matter through the one, and it paſſes too eaſily through the other; its Effort is abated, and thus the Spring is diminiſhed.

4. Does the Exceſs of Contraction, or of Dilatation, proceed to a certain Point? The ſubtile Matter finds no more Paſſage, or at leaſt it paſſes without Effort, without dilating or ex-

tending the Interſtices; and thus the Spring is loſt.

Eud. After this one may preſently comprehend why Lead, ſoft Wax, and ſoft Bodies, have ſo little Elaſticity.

Ariſt. That is becauſe thoſe Bodies having too flexible Parts, or too great Pores, give too free a Paſſage to the ſubtile Matter.

Eud. But Steel, which has never been tempered, has however ſtiff Parts, and yet but little Spring.

Ariſt. This Steel has little Spring, becauſe the Corpuſcles of Fire, for want of tempering, have been too long Time agitated in its Pores, and have too much enlarged them by the Continuance of their Agitation.

Eud. By a contrary Reaſon tempered Steel ought to have much more Elaſticity.

Ariſt. Without doubt, becauſe the Liquor has contracted its Pores, and extinguiſhed the Corpuſcles of Fire.

Eud. But why does the very tempering itſelf give little Elaſticity to Steel that is too hot?

Ariſt. Becauſe then the Exceſs of Heat, notwithſtanding the Liquor which cools the Steel, renders its Pores ſomething too large.

End. Beat the Steel, and its Spring is improved.

Ariſt. One ſees the Reaſon of that immediately, the Pores which were too large are contracted.

Eud. But why does the Steel loſe this acquired Force ſo quickly in a Fire too violent?

Ariſt. Becauſe the exceſſive Agitation of the Corpuſcles of Fire enlarges its Pores too much. Thus in order to give Elaſticity to the Steel in the tempering, there muſt be a certain Degree of Heat.

Eud. Thus the Elaſticity of Steel ſeems to be handſomly explained. But why has green Wood ſo much Elaſticity, in Compariſon of Wood that is dry and Worm-eaten?

Ariſt. Becauſe the ſubtile Matter by Virtue of its paſſing through the Interſtices of Wood too dry and Worm-eaten, has therein made itſelf more free Paſſages than in the green Wood, and by much too free. It finds in the Pores of the green Wood a Liquor, Juices and Obſtacles, which it does not meet with in that which is old and Worm-eaten.

Eud. I ſee what you are about to ſay of a Bow, which unbends, as it were, of itſelf, or loſes its Elaſticity, by Reaſon of its having been bended too long a Time.

Ariſt. When the Bow is bended, the Pores which are toward the convex Surface are enlarged, and thoſe which are toward the concave Surface are contracted. Leave the Bow at Liberty to unbend itſelf: The ſubtile Matter which glides through the large Pores accelerates its Motion, inſinuates itſelf, and flows with Violence into the ſmaller ones. Theſe are dilated, and thoſe contracted proportionally;

ly; the Bow is unbended. Has it been too long Time bended? The ſubtile Matter, by Means of its ſtriking againſt the cloſed Pores, or againſt the ſolid Parts, has made itſelf a free Paſſage. From the Time that it paſſes freely, it makes no more Effort to enlarge the Interſtices. Hence no more Spring, and the Bow refuſes to ſhoot the Arrow.

Eud. The Spring of the Air ought, I think, to be finally loſt, or diminiſhed at leaſt as well as that of a bended Bow. However it is neither loſt nor diminiſhed. A Portion of Air extraordinarily compreſſed, appeared ſtill to have the ſame Force of Elaſticity after 16 Years Preſſure[r].

Ariſt. The Elaſticity * of the Air ought not to be changed like that of mixed Bodies: For 1. The Air being a more ſimple Body has not ſo many Interſtices, it does not furniſh ſo many new Paſſages to the ſubtile Matter.

2. As the Pores of the Air are very ſtrait, the ſubtile Matter does nos paſs through them charged with foreign Corpuſcles, which contribute very much to cauſe an Alteration in more groſs Bodies.

3. The Particles of the compreſſed Air being interwoven with one another, and ſtraitly united, afford leſs Acceſs to the ſubtile Matter, and the ſubtile Matter makes itſelf new Paſſages with greater Difficulty. Hence the Spring

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[r] Hiſt. de l'Acad. 1695. p. 368. * See CONVERSAT. XXIII.

of the Air ought to be preſerved a longer Time. It is actually preſerved a longer Time, and after 16 Years Compreſſion in a kind of Fuſee, it is ſtill found in a Condition to drive out a Ball with Violence, and convey Death to 30 Paces Diſtance.

Eud. When one knows thus far the Properties of Elaſticity, one knows the ſecret Principle which animates a Watch, if I may ſpeak ſo.

Ariſt. This ſecret Principle is the Spring of a thin Plate of Steel rolled up upon itſelf in the Form of a ſpiral Line, and incloſed in the Barrel of the Watch. This Plate has unequal Pores. Thoſe of the concave Surface are leſs, as in the bent Bow. Thoſe of the convex Surface are bigger. The ſubtile Matter which runs eaſily in the bigger Pores, meeting with Obſtacles in the leſs, daſhes againſt and ſtrikes them, by its repeated Blows opens a Paſſage for itſelf, and accelerates its Motion. This redoubled Motion ſeparates the oppoſite Parts of the Pores, and dilates them, and thus gradually the Plate of Steel is unwound. The Effort of the Matter which endeavours to flow in a right Line, according to the ſecond Rule, from one Extremity of the Plate to another, aſſiſts the Explication. The ſmall Chain, which penetrates into the Barrel, receives its Motion from the Spring that is unfolded, and communicates it to the Wheels of the Watch. The Hand of the Watch, which is fixed to the Axle-tree of the Wheel that moves moſt ſlowly, goes about alſo after an imperceptible Manner, and by its inſenſible Motion, marks out the divers Moments of that Life, which paſſes away as imperceptibly as the Motion of the Hand itſelf.

Eud. I am delighted to ſee you diſcover how Nature produces the aſtoniſhing Effects of Elaſticity. But let us at laſt ſay ſomething of the Softneſs of Bodies.

Ariſt. I always find a new Pleaſure in hearing you upon a new Subject.

Eud. They call ſoft Bodies, Bodies which are eaſily compreſſed without endeavouring, at leaſt in a viſible Manner, to reſume their former Figure. What then is the Softneſs of Bodies? The Facility which their Parts have to be looſed from, and to move upon one another, without any ſenſible Effort to reſtore themſelves to their former Situation. Whence finally proceeds this Facility, this particular Diſpoſition? From the poliſhed Surface of the inſenſible Parts, and from the Action of the ſubtile Matter, which running through a Thouſand and Thouſand Places in the ſoft Bodies, moves, agitates and ſhake their Parts, ſo that the moved, ſhaken and agitated Parts which are attached to one another by very ſmall Surfaces, can be broken, looſed, and ſlide upon one another; without any Thing obliging them to reſume their former Situation; becauſe if the ſubtile Matter find ſome Paſſages ſtopped, it finds others free, or makes itſelf ſome new ones without any Obſtruction. Hence ſoft Wax immediately aſſumes under the Hand, and retains indifferently all Sorts of Figures; and you may ſee the Figures of Tygers and Lions upon Confections equally ſweet, ſoft and delicious.

Let us conclude our Converſation with an Experiment. Run two Pins into the two Extremities of a Stick about three Foot long, dry and as large as your Arm. Place two Glaſſes half full of Water upon two Tables of equal Height, about three Foot diſtant from one another. Put the Stick in an horizontal Situation, ſo that the two Pins may reſt upon the Brims of the two Glaſſes. Strike the Middle of the Stick violently, and you may ſee it broken cleanly notwithſtanding its Bigneſs, without breaking the Glaſſes, however brittle they be. If the two Extremities of the Stick reſted upon two Threads hung up perpendicularly, we might ſee the like Effect. Why is the Stick broken?

Ariſt. The Middle of the Stick, the Point ſtruck is compreſſed, and immediately receives a ſudden Impreſſion of the Blow. It paſſes to the Extremities but ſucceſſively, and by a great Number of Parts which receive it the one after the other, and the one from the other, like ſo many elaſtick Bodies ranged upon the ſame Line. Hence it is that the Middle, the Point ſtruck yields immediately, and before the reſt: And thus the Stick is broken.

It is not broken without obſerving punctually the Laws of Nature. It takes the moſt eaſie Courſe. To avoid breaking, notwithſtanding the Effort of the Blow, it muſt have yielded and deſcended with the ſame Velocity, or much the ſame, in all its Length. But in order to yield at that Rate, more Force muſt have been uſed. It muſt have driven away with the ſame Velocity a Maſs of Air as large and long as the Stick; which would have required more Force. The Force ought to increaſe in Proportion, when a greater Maſs is to be moved with the ſame Velocity.

Eud. But why are not the Glaſſes broken? Why do not the two Threads that are ſuſpended break aſunder?

Ariſt. When the violent, but ſucceſſive Impreſſion reaches the two Extremities of the Stick, they are elevated both the one and the other, in Proportion as the Middle yields and deſcends in the Fracture; and this Elevation removes from the Glaſſes or ſuſpended Threads that Impreſſion which might break in Pieces the one, and break aſunder the other.

Eud. All Bodies, hard, elaſtic and ſoft, often ſtrike againſt one another; and in this they always obſerve ſome particular Rules, which well deſerve a particular Converſation.

CONVERSATION X.

Upon the Rules of the Percuſſion of hard Bodies.

Ariſt. PRAY, *Eudoxus*, endeavour to make me underſtand thoſe Laws of Nature, ſo exactly obſerved in the Percuſſion of Bodies,

Eud. In order to diſcover and conceive thoſe Laws or Rules the more eaſily:

1. Let us ſuppoſe that hard Bodies are perfectly hard, elaſtick Bodies perfectly elaſtick, and ſoft Bodies perfectly ſoft. I call perfectly hard Bodies, Bodies incapable of changing Figure by a Stroke. I call thoſe perfectly elaſtick Bodies, in which the Force of unbending is equal to that of bending. By perfectly ſoft Bodies I underſtand, Bodies which are flatted by the Stroke without reſtoring themſelves in any Manner.

2. Let us examine the Stroke of two Bodies of the ſame Species, of two ivory Billiard-Balls. Let us ſuppoſe that the Stroke of thoſe two Bodies happens directly, and in a free *Medium*, or ſuch as gives no Obſtacle to their

Motion, and which takes nothing from their Force.

3. Let us take Notice that in the Stroke the Force of Percuſſion anſwers to the Reſiſtance; ſince a Body moved has no Liberty, no Aim, and the Queſtion is about its making Way for itſelf to continue in Motion according to the ſame Direction.

4. Laſtly let us conſider the Stroke of Bodies in three different Caſes; 1. When a Body moved ſtrikes againſt a Body in Reſt. 2. When a Body that has more Velocity overtakes a ſlower Body that goes before it. 3. When two Bodies meet one another with oppoſite Forces equal or unequal.

Ariſt. What ought to happen in thoſe three Caſes, to hard, elaſtick, and ſoft Bodies?

Eud. Let us ſpeak firſt of the Stroke of hard Bodies.

RULE I.

If a Body in Motion ſtrike another at Reſt, it puts it into Motion.

The Body ſtruck is moved after the Stroke, or elſe reſiſts the Force which ſtrikes it: But it does not reſiſt this Force neither of itſelf, ſince of itſelf it has no Efficacy, and is in an entire Indifferency as to Motion or Reſt; nor by any Property of Reſt, ſince Reſt which is not ſuſceptible of more or leſs is incapable of reſiſting Motion, whoſe Velocity is ſuſceptible of Degrees multiplied *in infinitum:* Conſequently the Body ſtruck is moved after the Stroke. Therefore a Body moved, which ſtrikes another in Reſt, puts it into Motion.

RULE II.

A Body in Motion, which moves another at Reſt, imparts to it of its Force in Proportion to the two Maſſes.

A Body moved, which ſtrikes a Body in Reſt, imparts to it ſo much of its Force preciſely as is neceſſary to remove the Obſtacle which proceeds from the Impenetrability of the Body ſtruck, and in vain would it impart more or leſs. Now to remove this Obſtacle there muſt be imparted, and it is ſufficient to impart a Force to the Body at Reſt, in Proportion to the two Maſſes. Then the equal and determinate Parts of the two Bodies, having equal Forces, ought to go both together with the ſame Direction and with equal Velocities, without the one ſtaying or retarding the Motion of the other. Therefore a Body moved, which moves a Body in Reſt, imparts a Force to it in Proportion to the two Maſſes.

In a Word, ſeparate the two Bodies into equal Parts, and divide the Motion into as many equal Parts; then impart to the equal Parts of the two Bodies equal Quantities of Motion:

Such is the Diſtribution of Motion in the Stroke of a Body in Reſt. Hence if the Body which ſtrikes it is equal in Maſs, it imparts one half of its Force. Is it ſubduple? It imparts two Thirds. Is it double? It imparts one Third, *&c.*

RULE III.

If a Body which has more Velocity, ſtrike another that goes before it, it will diſtribute its Exceſs in Proportion to the two Maſſes; and after the Stroke they will both go together with the ſame Velocity.

If the firſt impinged againſt the ſecond in Reſt, with a Quantity of Motion equal to its Exceſs of Velocity, it would diſtribute this Quantity of Motion in Proportion to the two Maſſes by the ſecond Rule. But this is as if it found it in Reſt with a Quantity of Motion equal to its Exceſs of Velocity: For there is no Regard to be had in the Stroke to the common Velocity, or that which is found alike in both Bodies. It is nothing in Regard of the Percuſſion, becauſe it is ſo far from contributing towards it, that it ſnatches away one Body from the Stroke of another: Therefore, *&c.*

RULE IV.

If two Bodies ſtrike one another with contrary and equal Forces, what will happen? They will be reflected with the ſame Forces.

They muſt be reflected after this Manner, or they muſt loſe their Forces in the Stroke; in ſhort, they will not go forward, ſince having oppoſite and equal Forces, they can neither overcome nor yield: Now they will not loſe their Force by the fourth general Rule, ſince they will communicate none of it: To communicate it, is to prevail; and neither the one nor the other will be victorious. Therefore they will be reflected with the ſame Forces.

RULE V.

If two Bodies ſtrike one another with contrary Directions and unequal Forces, they will go after the Stroke toward the ſame Place, according to the Direction of the ſtronger.

The ſtronger will continue to move in the ſame Direction, ſince being ſtronger it ought to prevail, and if it communicate of its Exceſs of Force, it will only diſtribute it in Proportion to the two Maſſes to remove all Obſtacles to its Direction. The weaker will return back again. In a Word, it ought to go forward, or reſt, or be reflected. It will not go forward; for being the weaker, it cannot overcome the ſtronger, which oppoſes to it its Impenetrability. It will not reſt, ſince by the ſame Reaſon it will communicate nothing, and conſequently will loſe nothing of its Force. Therefore it muſt return back. Now the ſtronger cannot move with the ſame Direction, and the weaker be reflected after the Stroke, but that they muſt both go toward the ſame Place, following the Direction of the ſtronger: Therefore, *&c.*

Ariſt. But if the weaker have preciſely ſo much Velocity before the Stroke as the ſtronger has, what ought to happen?

Eud. The weaker ought to be reflected with the ſame Velocity preciſely, ſince it is ſufficient and neceſſary for removing all Obſtacle to the Motion of the ſtronger.

Ariſt. What if the Velocity of the weaker do not equal the Velocity of the ſtronger before the Stroke?

Eud. The weaker will have more Velocity after the Stroke, than it had before it: It muſt have at leaſt as much as the ſtronger, that it may go before it; otherwiſe it would reſiſt by its impenetrability, and would be the weaker without being ſo.

Ariſt. But finally, what if the weaker have more Velocity before the Stroke?

Eud. Let us begin with ſome Obſervations.

1. Elaſticity is the Force which makes a Body changed as to its Figure, reſume it as of itſelf. In order to reſume it there muſt be a Force equal to that which changed it. Therefore the Force by which an elaſtic Body is reſtored, is equal to that which changed, flatted, or preſſed it in.

2. When an elaſtic Body reſtores itſelf, it repels with all its Force the Body which ſtruck it. Therefore it thruſts it back with a Force equal to that which ſtruck it; therefore it endeavours to reſtore it its former Velocity, but with an oppoſite Direction.

3. Here I diſtinguiſh two Forces, or two Motions, the one direct, the other elaſtic. I call the direct Motion, that by which an elaſtic Body ſtrikes another at firſt. I call the elaſtic Motion, that which proceeds from the Spring, and by which a Body flatted in the Stroke reſumes the Figure which it loſt.

4. In two Bodies, which are reſtored after the Stroke, the two elaſtic Motions being contrary, they are reflected by one another toward oppoſite Parts. For which Reaſon in a Body, which ſtrikes and communicates its direct Motion, the elaſtic Motion is contrary to the direct Motion, which this Body preſerves; in the Body ſtruck, which receives direct Motion from the other, the elaſtic Motion favours the direct Motion.

Finally, let us give two Balls, two elaſtic Bodies, the Names of *B* and *C*. Theſe Names expreſs nothing uſeleſs, and yet are as ſignificant as the moſt harmonious and comprehenſive Names.

RULE I.

B *ſtrikes* C *equal and at reſt: What happens? In this Hypotheſis*, C *being ſtruck, is moved in its Turn with as much Force as* B *had before the Stroke, and* B *reſts.*

1. *C* being ſtruck moves with as much Force, as *B* had before the Stroke. *C* cannot receive from *B* the half of its direct Motion, being doubled by the Power of the Spring, without moving with as much Force as *B* had before the Stroke. Now *C* being equal and at Reſt, receives from *B* the half of its direct Motion, in order to remove all Obſtacle, by the ſecond Rule of hard Bodies; and this half of the Motion is doubled by the Force of the Spring, ſince the elaſtic Motion anſwers to the Compreſſion, the Compreſſion to the Percuſſion, and the Percuſſion to the direct Motion communicated in the Stroke, and the elaſtic Motion in the Body ſtruck, ſeconds the direct Motion. Therefore, *&c.*

2. *B* reſts after the Stroke. A Body which unites two equal and contrary Forces is ſtopt and reſts, becauſe it cannot comply with both, nor yield to the one rather than the other,

and becauſe thoſe two Forces are loſt in the imperceptible Parts, or are inſenſibly diffuſed into the Air. Now *B* reunites two equal and contrary Forces, namely, the half of the direct Force, and an equal and oppoſite elaſtic Force: For the elaſtic Force of the Body which ſtrikes, is reflected by the elaſtic Force of the other, with a Direction contrary to that of the direct Force. Therefore *B* reſts after the Stroke, ſo that the Truth of the Rule is obvious to the Eye.

Ariſt. Conſequently if *B* is moved before the Stroke with ſix Degrees of Force, *C* will have ſix after the Stroke, three of the direct Force, and three of the elaſtic Force; and *B* in its Turn will remain without Motion.

I think I apprehend in this Principle, *Eudoxus*, the Reaſon of a pretty ſingular Fact. Upon a Plane, and upon a ſtrait Line, I range five or ſix Balls equal and contiguous: One Ball, which ſingly ſtrikes the firſt of theſe ranged Balls, makes the laſt preciſely to move away. If two Balls which touch one another, go together to ſtrike the firſt, you may ſee the two laſt move away. Three of them make three to move away, *&c.* Why? The Ball, which goes alone to ſtrike the firſt of the ranged Balls, beſtows on it the half of its Force doubled by the Efficacy of the Spring, loſes the reſt by the Oppoſition of its own elaſtic Force reflected by the Action of the Spring of the Ball that is ſtruck, and ceaſes to move,

move; after the ſame Manner as *B* which ſtrikes *C* equal, and at Reſt. The firſt Ball being ſtruck, ſtrikes the ſecond after the ſame Manner, and alſo loſes its Force, *&c.* The laſt alone, which meets with no Ball in its Way, receives the whole Impreſſion without communicating or loſing it; and moves away alone. When two go to ſtrike, their Impreſſions are ſucceſſive. At firſt the Action of the former paſſes as far as the laſt of the ranged Balls; and makes it run off; the Action of the other immediately follows, and makes the laſt but one paſs off to accompany the laſt, *&c.*

RULE II.

Eud. *If* B *being greater ſtrike* C *that is leſs and at Reſt, they will both go after the Stroke toward the ſame Place.*

They will go, I ſay, with the ſame Direction after the Stroke, if *B* preſerves its direct Force; but *B*, no doubt, will preſerve it. 'Tis true it will loſe what paſſes into *C*, and the contrary elaſtic Force ought to deſtroy as much again: But as it will not give to *C* the half of its Force being greater than *C*; but will only give preciſely in Proportion to the two Maſſes, and as the Force of the Spring will deſtroy no more of it than is communicated, ſince it anſwers to the Force communicated; it ought to reſerve to itſelf ſome Degrees in order to follow the Traces of *C*.

B being double, *e.g.* ſtrikes, with a Force of ſix Degrees, *C* being Subduple and at Reſt; what will happen?

Ariſt. According to your Principle *B* will impart two Degrees of Force to *C*; theſe two Degrees will be doubled by the Force of its Spring; *B* which will loſe theſe two Degrees, ought moreover to loſe other two by the contrary Force of its Spring: Therefore *B* and *C* will go toward the ſame Place, *B* with two Degrees, and *C* with four.

RULE III.

Eud. B *goes from the Weſt to ſtrike* C, *being greater and at Reſt; what happens?* B *is thruſt back toward the Weſt.*

It muſt be thruſt back toward the Weſt, if its elaſtic Force be ſtronger than the direct Force which remains to it: But its elaſtic Force is ſtronger. For the elaſtic Force anſwers to the Motion communicated in the Stroke, and this Motion exceeds that which remains in *B*. *B* being the leſs ought to communicate more than a half of its Force, ſince it communicates of it in Proportion to the two Maſſes. Therefore if *B* go to ſtrike *C*, being greater and at Reſt, it ought to be reflected.

Let us ſuppoſe *B* a Subduple; it has ſix Degrees of Force, and goes to ſtrike *C*.

Ariſt. *B* will recoil with two Degrees. For at firſt it will impart four according to the Proportion of the Maſſes: Conſequently the Motion of the Spring, which tends to drive it back, will be of four Degrees. Of thoſe four Degrees two will be deſtroyed by the two oppoſite Degrees of direct Motion, which it retains. There will remain in *B* two Degrees of elaſtic Force: Therefore it ought to return with two Degrees.

RULE IV.

Eud. *If* C *go before, and* B *being equal, but having more Velocity meet with it, they will both continue to go forward with the ſame Direction, but will make an Exchange of Velocity.*

1. They will continue to go forward; for they will loſe nothing of their common Velocity, ſince it is no Way employed in the Stroke. If *B* and *C* have each two Degrees of common Velocity, the two Degrees of *C* will paſs into two Degrees of *B*.

2. They will make an Exchange of Velocity, if after the Stroke *B* only retains its common Velocity, and *C* have, beſide its common Velocity, a Velocity equal to the Exceſs which was found in *B* before the Stroke: Now, 1.

B will only preſerve its common Velocity; for it will give an half of its Exceſs of Velocity to remove the Obſtacle of Impenetrability, and will loſe the other half by the contrary Force of its Spring. 2. *C*, beſide its common Velocity, ought to have a Velocity equal to the Exceſs which was found in *B* before the Stroke, ſince it will receive the half of this Exceſs doubled by the Force of its Spring. Therefore, if *C*, &c.

This being granted; if *C* precede with four Degrees of Velocity, and *B* follow with 12 Degrees, what will happen?

Ariſt. *B* will immediately communicate four Degrees to *C*, in order to remove the Obſtacle of Impenetrability, and theſe four Degrees will be doubled by the Spring. Conſequently *C*, which according to the Propoſition had four before the Stroke, will have 12 after the Stroke. Of the eight which remain to *B*, after it has given away four, it will loſe four deſtroyed by the contrary Force of its Spring. Therefore *B*, which had 12 before the Stroke, will retain but four; and *C*, which had only four, will have 12 after the Stroke: Therefore they will continue to move with the ſame Direction, but with an Exchange of Velocity.

RULE V.

Eud. *If* B *and* C *ſtrike one another with contrary Directions and equal Forces, they will be repelled with the ſame Forces.*

They will be thruſt back and reflected with the ſame Forces, if the Efficacy of the Spring reſtore them, after the Stroke, the Forces which they ſhall have loſt in the Stroke by the Compreſſion; for they will not move forward after the Stroke, ſince they are impenetrable, and one cannot overcome the other, having preciſely equal Forces. But the Efficacy of the Spring will reſtore them the Forces which they ſhall loſe by the Compreſſion in the Stroke, ſince this Efficacy anſwers to the Compreſſion, as the Compreſſion anſwers to the Force employed and communicated in the Stroke. Therefore if *B* and *C* ſtrike one another with contrary Directions and equal Forces, they will recoil with the ſame Forces.

RULE VI.

If B *and* C *having equal Maſſes ſtrike againſt one another with unequal Forces, they will return interchanging their Forces.*

For 1. They will loſe their common Forces in the Stroke by the Compreſſion or flatting;

but the Spring ought to reſtore them with contrary Directions. 2. The ſtronger will give the half of its Exceſs to the weaker, in which the Force of the Spring will double it, while it will deſtroy the other half in the ſtronger. Therefore if *B* and *C*, *&c.*

Let *B* come with ſix Degrees of Force, and *C* with two.

Ariſt. *C* ought to be reflected with ſix Degrees, and *B* with two; for they will loſe by the Stroke, each two Degrees of common Force; but the Spring will reſtore them with contrary Directions. *B* will communicate two Degrees of the four of its Exceſs. It will loſe the other two by the contrary Force of the Spring. Conſequently it will have two preciſely to return back. Beſide its two Degrees of common Force, *C* will receive two by Communication, and theſe two will be doubled by its Spring: Therefore *C* ought to return with ſix Degrees of Force, and *B* with two.

But if *B* and *C* ſtrike one another with equal Velocities, having unequal Maſſes?

Eud. 1. *In this Hypotheſis the leſs will always recoil:* For being the weaker it will ſtrike with all its Force, and will loſe it all in the Stroke; but the Spring will reſtore it to it for driving it back. Moreover it will ſhare in the Exceſs of the ſtronger. Therefore it will always recoil.

2. *The greater will ſometimes ceaſe its Motion.*

It cannot have, after the Stroke, as much direct Force as elaſtic, without reſiſting; two internal equal and contrary Forces are null. But the greater will ſometimes have, after the Stroke, as much direct Force as elaſtic. Let us ſuppoſe that *B* being triple comes with ſix Degrees of Velocity, and *C* with ſix. In this Hypotheſis *B* ought to have, after the Stroke, a direct Force, and an elaſtic one, equal. For *B* having ſix Degrees of Velocity, and three of Maſs, has 18 Degrees of Force, ſince the Force is the Product of the Maſs by the Velocity. Of the 18 it will loſe ſix common, which the Spring will reſtore it to make it recoil. Of the 12 which remain it will communicate three; for being triple it will give it a fourth Part of its Force. There remain nine. Of theſe nine Degrees it will loſe three, which are deſtroyed by the contrary elaſtic Force, which anſwers to the Force communicated: Therefore it will have ſix Degrees of direct Force, and as we ſaid juſt now, ſix Degrees of contrary elaſtic Force. Therefore the greater will ſometimes have as much direct, as elaſtic Force; therefore after the Stroke it will unite two equal and contrary Forces; therefore it will reſt ſometimes.

3. *Sometimes the greater will recoil.*

When the elaſtic Force prevails over the direct, the Body muſt recoil, ſince that is contrary to this. But the elaſtic Force will ſometimes prevail. Let us ſuppoſe in *B* five Degrees of Maſs, and four of Velocity; in C three Degrees of Maſs, and four of Velocity. The elaſtic Force will be predominant in B, if it retain preciſely ten Degrees of elaſtic Force to rebound: But it will preciſely retain 10 for recoiling. For B having five Degrees of Maſs, and four of Velocity, has 20 Degrees of Force; C having three Degrees of Maſs and four of Velocity, has 12 Degrees of Force. Therefore B will immediately loſe 12 Degrees of common Force in the Stroke, ſince by theſe 12 Degrees it will impinge againſt a contrary Force of 12 Degrees; but the Spring will reſtore them. Of its Exceſs of eight Degrees, which will remain after the Loſs of 12, it will give three to C, in Proportion to its Maſs; and five remain. The elaſtic Force for recoiling, anſwers to the Force communicated or loſt in the Stroke: Therefore it will be 15 Degrees. But B retains ſtill five Degrees of direct Force, which it ought to loſe by deſtroying five Degrees of the elaſtic: Therefore B will retain preciſely 10 Degrees for recoiling. Therefore ſometimes the greater will be reflected.

4. *Sometimes the greater will continue after the Stroke to follow the ſame Direction.*

For ſometimes after the Stroke, its direct Force will be greater than its elaſtic. Let us ſuppoſe in B five Degrees of Maſs, and three of Velocity, and in C one Degree of Maſs and three of Velocity: B will retain five Degrees of effectual Force for advancing. In ſhort, *B* having five Degrees of Maſs and three of Velocity, it has 15 Degrees of Force; *C* having one Degree of Maſs and three of Velocity, it has three Degrees of Force. Of the 15 Degrees of direct Force *B* will immediately loſe three by the encountering of the three Degrees of *C*, but which will be reſtored to it; of the 12 remaining it will give two to *C*; for being quintuple it will communicate the ſixth Part of its Exceſs; 10 remain. Of theſe 10 it will loſe five by the contrary Force of Elaſticity, ſince it anſwers to the Force deſtroyed or communicated: Therefore it will retain five in order to move forwards.

Therefore if *B* and *C* ſtrike one another with equal Velocities, having unequal Maſſes, the leſs will always rebound: Sometimes the greater will reſt; ſometimes it will recoil; and ſometimes it will continue to follow the ſame Direction after the Stroke.

By the Help of theſe Lights one may enter into a more exact Detail. You will explain to me, *Ariſtus*, at your Leiſure the Rules which ought to be obſerved in the Percuſſion of ſoft Bodies.

CONVERSATION XII.

Upon the Percuſſion of ſoft Bodies.

Eud. WILL you diſcover to me, *Ariſtus*, thoſe Secrets which Nature has imparted to you?

Ariſt. When one comprehends the Rules obſerved in the Percuſſion of hard and elaſtic Bodies, it is eaſie to underſtand thoſe which ought to be followed by Bodies that are ſoft.

RULE I.

If B *ſtrike* C *at Reſt, it will give it ſome of its Force, in order to make itſelf a free Paſſage.*

Since *C* will not reſiſt either by itſelf, being very indifferent to Motion or Reſt; nor by its Reſt: Reſt makes no Reſiſtance to Motion, by the firſt Rule of hard Bodies.

RULE II.

B *ought to impart Motion to* C *at Reſt, in Proportion to the two Maſſes.*

For, in a Word, it will impart preciſely ſo much as is neceſſary to make itſelf a free Paſſage, if it communicate neither more nor leſs, it muſt impart it in Proportion to the two Maſſes; the half if *C* is equal; the third Part, if it is Subduple; and two thirds, if it is double: Then will they go with the ſame Velocity, without any Obſtacle. Therefore, &c.

RULE III.

If B *overtakes* C, *which goes before,* B *will divide the Exceſs of its Force with* C *in Proportion to their Maſſes.*

In ſhort, by this Exceſs *B* ought to ſtrike *C*, as if it were at Reſt: No Regard muſt be had in the Stroke, to the common Motion of the two Bodies. By this Motion the one Body runs from the other; this Motion is uſeleſs with Regard to the Stroke: Now if *B* found *C* at Reſt with its Exceſs of Force, it would communicate it in Proportion to the two Maſſes: Therefore if *B* overtake *C*, which goes before, &c.

RULE IV.

If B *and* C *ſtrike one another with equal Forces, they will remain at Reſt after the Stroke.*

They muſt ſtop if they loſe their Forces in the Stroke, without having them reſtored by any Thing; but 1. They will loſe their Forces like elaſtic Bodies. They will paſs into the inſenſible Parts; ſince the inſenſible Parts will ſtrike, break, reflect, and give one another a Thouſand different Directions in Proportion to their Texture, and the common Forces of the two Bodies. 2. Nothing will reſtore them their common Forces, ſince they have no Elaſticity; Therefore, &c.

RULE V.

If B *and* C *ſtrike one another with unequal Forces.*

They will loſe their common Motion; it will become proper to the imperceptible Parts by the fourth Rule: But the ſtronger will divide its Exceſs of Force with the weaker in Proportion to the two Maſſes, ſince by this Exceſs it will ſtrike the weaker, as if it found it at Reſt.

Eud. I look upon the Rule, which we have been diſcourſing of, as a Principle of a Thouſand and a Thouſand divers Effects in Nature,

Nature. Nevertheleſs it muſt be granted, *Ariſtus*, that among ſenſible Bodies there are none probably that are either perfectly hard, or entirely elaſtic, or abſolutely ſoft; but they ought to follow the Rules juſt laid down, more or leſs, exactly in Proportion as they approach more or leſs to Bodies perfectly hard, elaſtic, or ſoft.

Let us at laſt ſee the Uſe of Motion and its Effects in the different Species of Bodies, which compoſe the Univerſe. But let us begin with forming ſome general Idea of the Univerſe itſelf, by conſidering the Sphere which Art preſents to our Eyes.

CONVERSATION XIII.

Upon the Sphere.

Eud. WE have not, *Ariſtus*, (either you or I) Eyes piercing enough to penetrate ſo far as the Surface of the World; we don't ſee the external Figure of it: But if we judge of it by the common Perſuaſion, and by what is offered to our Senſes, when the Weather is ſerene, and the Heaven ſparkles with Stars, the World is round: It is a Sphere.

Ariſt. One may diſtinguiſh in the Sphere of the Heavens, as one does in an artificial celeſtial Sphere, different Parts, an Axis, two Poles, ſix large Circles; the Zenith, the Nadir, four Cardinal Points, the two Points of the Equinoxes, the two Points of the Solſtices, four ſmall Circles, and five Zones.

Eud. You ſeem to have, *Ariſtus*, a juſt Idea of the different Parts of the artificial celeſtial Sphere, *Fig.* 14.

Ariſt. 1. The Axis of the Sphere is the Line that paſſes thro' the Center of the Earth *(b)* eſteemed as the Center of the Sphere, or the Diameter *(a b c)* upon which the Sphere turns.

2. The

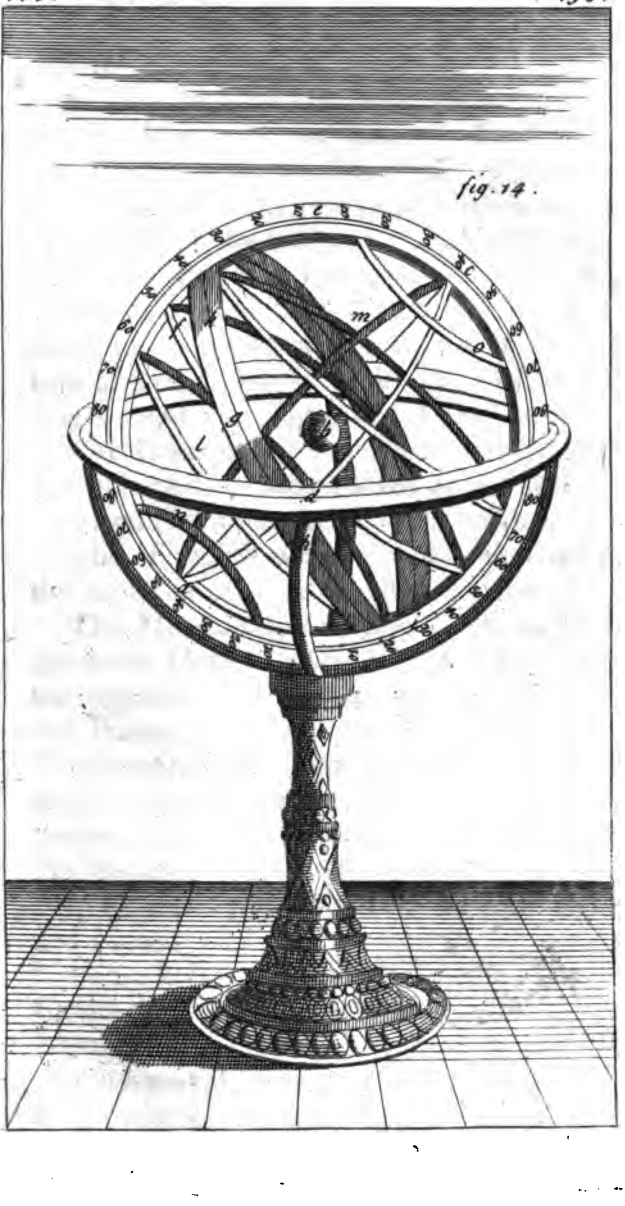

fig. 14.

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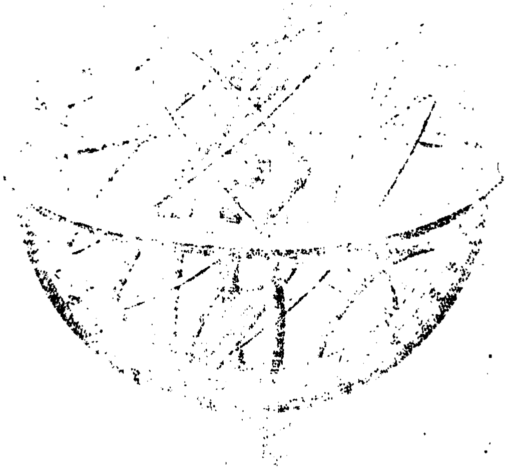

2. The two Poles *(a, c)* of the Sphere, are the two Extremities of the Axis.

3. The ſix large Circles have for their Center, the Center of the Sphere. Theſe Circles are, the Horizon, the Meridian, the Equator, the Zodiack, the Colure of the Equinoxes, and the Colure of the Solſtices. Every Circle contains 360 Parts or Degrees. An Arc of 90 Degrees, comprehended betwixt two Lines, diverging and united in a Point, is the Meaſure of a right Angle: A leſs Arc, of an acute Angle; and a greater Arc, of an obtuſe.

The Horizon *(d)* is a Circle which divides the Sphere into two halves of a Sphere, or into two Hemiſpheres, the one ſuperior, in the middle of which we are, and which we ſee; the other inferior, and which we ſee not.

The Horizon has its two Poles, as well as the other Circles. The Poles of a Circle are the oppoſite Points, equally diſtant from all the Points of the Circle. The Poles of the Horizon are called Zenith and Nadir: The Zenith is over our Head; the Nadir is the Point diametrically oppoſite. Hence every one has his Horizon, Zenith and Nadir; and whenever he moves, he changes Horizon, Zenith, and Nadir.

Four Points of the Horizon are the four Cardinal Points, the Eaſt, Weſt, South, and North. The Eaſt is that Point of the Horizon where the Sun riſes. The Weſt is that Point where the Sun ſets. The South, with reſpect to us, is that Point where the Meridian cuts the Horizon on the Side of the Sun; and the North, the Point oppoſite.

The Meridian *(e)* is a Circle, which paſſes both thro' the two Poles of the Sphere, and thro' the Zenith and Nadir, cutting the Horizon at right Angles, or without inclining more to one Side than the other.

The Equator *(f)* is a Circle, which cuts the Meridian at right Angles, and which is equally diſtant in all its Points from the two Poles of the Sphere.

The Zodiack *(g)* is a Circle, which cuts the Equator, making with it acute Angles of 23 Degrees and a half, or which is 23 Degrees and a half diſtant toward the two Poles. It has 16 Degrees of Breadth, or thereabouts. Its Breadth is divided into two equal Parts by a circular Line *(k)* which the Sun runs, or ſeems to run over in a Year; and this is the Eckliptick. The Zodiack has 12 Parts, every one of which has 30 Degrees, and contains a Conſtellation or Sign; that is, a certain Number, a Collection of Stars. They call thoſe Signs, going from the Weſt toward the Eaſt, *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, and *Piſces*. The two Points where the Ecliptick cuts the Equator, or Equinoctial Line, are the Points of the Equinoxes. When the Sun is in thoſe Points, the Length of the Light and Darkneſs is equal. The two Points, where the Ecliptick is fartheſt diſtant from the Equator toward the North and South, are the Points of the Solſtices, where the Sun begins to return toward the Equator.

The Colure of the Equinoxes *(h)* is a Circle, which paſſes both thro' the Poles of the Sphere, and alſo thro' the Points or Sections of the Equinoxes. The Colure of the Solſtices *(i)* is a Circle, which cuts the other Colure at right Angles, paſſing thro' the two Points of the Solſtices.

4. The ſmall Circles of the Sphere are thoſe which have not for their Center the Center of the Sphere, neither do they divide it into equal Parts: There are four of them, two Tropical, and two Polar, all of them parallel to the Equator. The two Tropics *(l, m)* are 23 Degrees and an half diſtant from the Equator, the one towards the South, and the other towards the North. This touches the Zodiac in *Cancer*, and is the Tropic of *Cancer*, and neareſt to us; the other in *Capricorn*, is the Tropic of *Capricorn*, and fartheſt from us: They are called Tropics, becauſe the Sun, whenever he touches the one, begins again to draw nearer to the other.

5. The Polar *(n, o)* are Circles 43 Degrees diſtant from the Tropics, and 23 and a half from the Poles. The Poles of the Zodiac are in the Polar Circles.

6. The Zones are the Spaces contained betwixt the Tropics and Polars. There are five

Zones; the torrid Zone, two temperate Zones, and two frigid. The torrid Zone is betwixt the two Tropics; the two temperate Zones are betwixt the Tropics and the Polars; and the two frigid Zones are betwixt the Polar and the Poles.

Thus, I think, you have the artificial Sphere deſcribed in few Words: But pray, *Eudoxus*, make me ſee with the Eye, if poſſible, where, in the Heavens, Aſtronomers place thoſe Circles, Points, and Zones.

Eud. The Seaſon and Weather are favourable enough. It is the Equinox, the Heaven is ſerene, and the Stars are brillant. Let us go up upon this Platform, where ſometimes I obſerve the Stars. This large Circle, whoſe Circumference terminates the Sight on all Sides, is the ſenſible Horizon, which only differs from the true one by a Semi-diameter of the Earth, ſuppoſing the Center of the Earth to be the Center of the World. The Point, where we ſaw the Sun this Morning riſe toward the left Hand, above the Horizon, is the Eaſt. The Point, where this Evening we ſaw the Sun go down toward the right, below the Horizon, is the Weſt. The horizontal Arc which we ſaw on the Side of the Sun, from the riſing to the ſetting, let it be divided into two equal Parts: The middle Point is the South. Let us turn our Eyes toward the Point directly oppoſite, that is the North. Lift up your Eyes, and you may ſee toward the North ſeven Stars very brillant, ſour of which are diſpoſed almoſt in the Form of an Oblong Square, and the other three in Form of the Arc of a Circle, and of a Tail. That is the Conſtellation which they call *Urſa Major*, or *Charles's Wain*. You may ſee at ſome Diſtance ſeven other Stars, which make much the ſame Figure, but ſhine with leſs Luſtre: This is the *Leſſer Bear*. The laſt Star of the Tail is the *Polar Star*; it is near the Arctic, or North Pole. The oppoſite Pole of the Heaven is the *Antarctic*, South, or Meridional Pole.

The firſt is elevated about 49 Degrees in regard of *Paris*, and the other as much depreſs'd below the Horizon.

Ariſt. Virgil inform'd me of that a long time ago.

Hic Vertex nobis ſemper ſublimis; at illum
Sub pedibus Styx atra videt, maneſque profundi *.

Eud. The Point of the Horizon where we are, is the Center of the Circle: The Point of the Heaven, the moſt elevated directly over us, is our Zenith, the Point directly oppoſite is the Nadir.

The Circle which paſſes through theſe two Points, and thro' the two Poles, is our Meridian: When the Sun is in it, it is Noon with reſpect to us, or the half of the Day. Hence, when one goes toward the Eaſt, or toward the Weſt, one changes both Meridian and Zenith.

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* Book I. of *Georg.*

The Circle which cuts our Meridian at right Angles, 90 Degrees diſtant from the Pole which you ſee, the Circle diſtant from the Pole 90 Degrees in all its Points; the Circle, in a Word, which the Sun deſcribes by his daily Motion at preſent, the 21ſt of *March*, the Day of the Equinox, is the Equator, or Equinoctial Line.

The Moon cuts the Equator, making acute Angles with it on both Sides; and the Circle which it deſcribes every Month, going obliquely, but very ſenſibly, from the Weſt toward the Eaſt, is in the Zodiac. The Planets, *Mercury*, *Venus*, *Mars*, *Jupiter*, *Saturn*, thoſe Species of Stars which we ſee ſhine without any ſparkling, while others ſend forth Rays on all Sides, are alſo in the Zodiac. The Planets make their Revolutions in the Zodiac, and according to *Tycho*, a famous Aſtronomer in this Order, *Fig.* 15. the Earth in the Center of the World, round about the Earth the Moon, the Sun carrying along with it *Mercury* and *Venus*, and round about it *Mars*, *Jupiter* and *Saturn*. The Planets make their Revolutions in the Zodiac round about the Sun, according to *Copernicus*, another famous Aſtronomer, and in this Order, *Fig.* 16. the Sun in the Center of the World, *Mercury*, *Venus*; the Earth with the Moon, *Mars*, *Jupiter*, and *Saturn*. We ſhall ſee one Day what we ought to think of the Situation of the Sun and Earth. However that be, the Moon has its different Phaſes in the Zodiac. It is there new, or in Conjunction, when it is betwixt the Sun and the Earth; Full,

fig. 15.

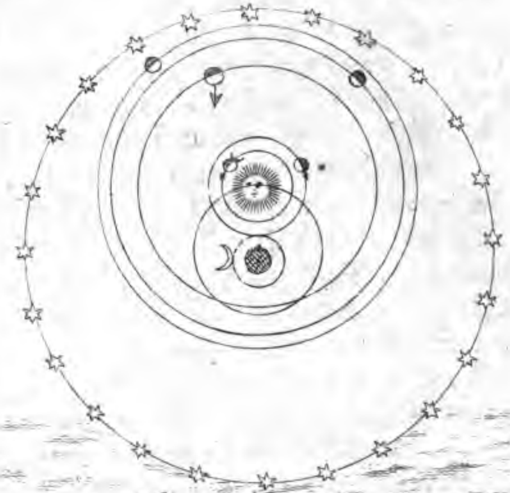
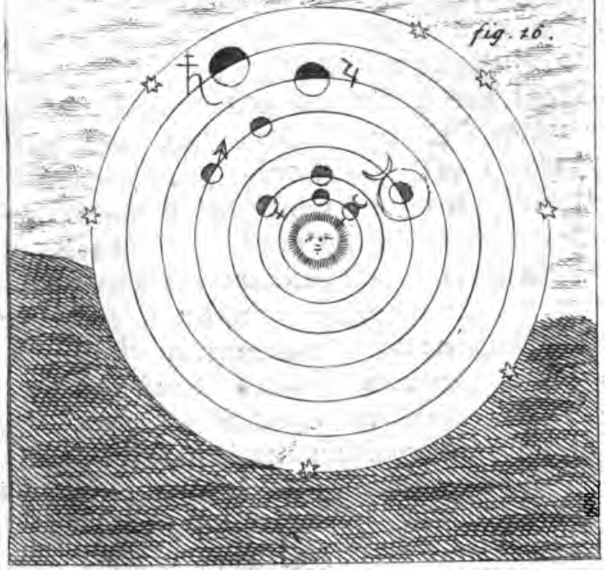


fig. 16.



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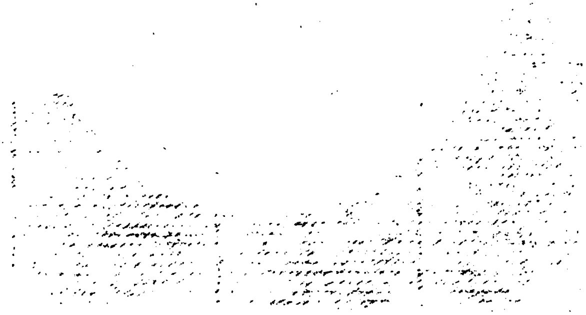

or in Oppoſition, when it is 180 Degrees diſtant from the Sun, or when the Earth is betwixt it and the Sun. It is in its Quadratures or Quarters, when it is three Signs or 90 Degrees diſtant from the Sun. Finally, the Ecliptick cuts the Equator in the Point where the Sun is on the Day of the Equinox.

Call to Mind the Point of the Horizon where you ſaw the Sun ſet this Day the 21ſt of *March.* Look toward the Eaſt, and ſee the oppoſite Point of the Horizon. The Circle which paſſes through thoſe two Points, and through the Poles, is the Colure of the Equinoxes; and the Circle which cuts it at right Angles is the Colure of the Solſtices.

The Circle parallel to the Equator, but nearer to us by 23 Degrees and an half, is the Tropic of *Cancer.* The Circle parallel to the Equator, but 23 Degrees and a half farther diſtant from us, is the Tropic of *Capricorn.* Look toward the North Pole. The Circle 23 Degrees and a half diſtant from the Pole, is the polar Circle. The Circle 23 Degrees and a half diſtant from the other Pole, and which we do not ſee, is the other polar Circle.

Laſtly, the intermediate Spaces are the Zones.

Ariſt, I have, I think, *Eudoxus,* a pretty clear Idea of the Sphere of the Heavens.

Eud. They eſteem the Earth itſelf as a Sphere, as a Globe. They give to it as to the Heaven, its Poles, its Circles, its Points, its Zones, ſo that the Poles, Circles, Points and Zones of the Earth, anſwer to the Poles, Circles, Points and Zones of the Heaven. This is what one may ſee with a Glance of the Eye in a celeſtial Sphere bored through, which contains in it a terreſtrial Globe. The Earth has its Parallels. Theſe are Circles parallel to the Equator, Tropics, and Polars.

The Spaces contained betwixt the Parallels and Meridians, are Climates. The Meridians are moveable, except the firſt which the *French* fix in the Iſland of *Fer*, the moſt weſtwardly of the *Canary* Iſlands, Laſtly, the Circles of the Sphere have their Uſes.

Ariſt. And thoſe Uſes are ſufficiently evident, after what we have ſaid.

1. One ſees the Eaſt and Weſt in the Points of the Horizon, where the Sun riſes and ſets; and the North and South in the Points of the Horizon that are cut by the Meridian. It is in the Horizon, that we ſee Night ſucceed Day, and Day ſucceed Night. The Horizon ſeparates the upper Hemiſphere from the inferior, the viſible from the inviſible in Regard to us.

2. The Meridian divides the World into two equal Parts, the one Eaſt, the other Weſt. Hence, the Sun being in the Meridian, it is Mid-day above the Horizon, and Mid-night below the Horizon. The Meridian ſerves farther to determine the Elevation of the Pole; ſince the Arc of the Meridian contained between the Pole and the Horizon, expreſſes the Height of the Pole. What is the Longitude of any Part of the Earth? It is its Diſtance

from the firſt Meridian, reckoning from Weſt to Eaſt. The Latitude is the Diſtance from the Equator. There is a North and South Latitude. Both the one and the other is determined by the Arc of the Meridian, or by the Degrees contained betwixt the Equator and any Place North or South.

3. The Equator divides the World into two equal Parts, the one South, and the other North. In this Circle the Equinoxes happen, about the 21st of *March*, and 23d of *September*. When the Sun is in this Circle, it is as long above the Horizon, as below it. Hence the Length of the Day and Night is equal. The Equator is moreover the Meaſure of Time, ſince the Sun runs over the 360 Degrees of this Circle in 24 Hours. What is the Declenſion of the Sun and Stars? Their Diſtance from the Equator, and the Degrees of the Meridian contained betwixt the Equator and Stars, are the Meaſure of their Declenſion.

4. The Sun, Moon, and Planets make their Revolutions in the Zodiack; and the Motion of the Sun, according as he approaches or removes from the divers Climates, ſo that his Rays are more or leſs oblique, make the different Seaſons; the firſt Equinox the 21ſt of *March*, and the Spring, by paſſing in the Space of three Months from the Equator to the Tropic of *Cancer*, where the Summer Solſtice happens the 21st of *June*, the Summer returning through other Signs in three Months from *Can-*

cer to the oppoſite Point of the Equator, where the ſecond Equinox happens the 23d of *September*; the Autumn, going in three Months from the Equator to the Tropick of *Capricorn*, when the Winter's Solſtice happens the 21ſt of *December*; and the Winter, returning from *Capricorn* in the Space of three Months, and through three other Signs, to the Equator.

5. One ſees in the Colures, though their Uſe does not ſeem very neceſſary, the Points of the Equinoxes and Solſtices.

Finally the ſmall Circles, the Tropicks and Polars divide the Earth and the World into five Zones.

Eud. It is worth while to obſerve farther the Poſition of the Sphere; that is the Situation of the Horizon in Relation to the Equator. Hence, there are three different Poſitions of the Sphere; one right, the other oblique, and the third parallel. It is right, when the Horizon cuts the Equator at right Angles. It is oblique, when the Horizon cuts the Equator at unequal Angles: It is parallel, if the Horizon is parallel to the Equator, or confounded with it. Thoſe who inhabit under the equinoctial Line have a right Sphere; we have an oblique; and if there are Men under the Poles, they have a parallel one.

Will you tell me, *Ariſtus*, what Stars aſcend above the Horizon, and deſcend below it every Day in a right Sphere, or with Reſpect to the Inhabitants of the equinoctial Line?

Ariſt. The Stars cannot all turn round about the Axis and Poles of the World every Day without aſcending all, or almoſt all, above the Horizon, and deſcending below the Horizon every Day in a right Sphere, ſince in a right Sphere the Horizon paſſes through the Poles. Now all the Stars turn ſenſibly about the Axis and Poles of the World every Day: Therefore all, or almoſt all the Stars aſcend above, and deſcend below the Horizon, every Day in a right Sphere.

Eud. But in the oblique Sphere, at *Paris*, for Example.——

Ariſt. Some Stars are there always above the Horizon, and others are never there. Let us ſuppoſe that the Height of the Pole is 49 Degrees; all the Stars contained in this Space, never deſcend below the Horizon, the Horizon being 49 Degrees below the Pole. All thoſe which are not above 49 Degrees diſtant from the oppoſite Pole, never aſcend above the Horizon; the Horizon being 49 Degrees above this Pole.

Eud. But laſtly in a parallel Sphere, under the Pole.——

Ariſt. One ought always to ſee there the ſame half of the Heaven: For one ought always to ſee there the half of the Heaven contained between the Pole and the Equator, ſince the Equator and Horizon is the ſame Thing. Now this half of the Heaven is always the ſame;

it is moved parallel to the Equator or the Horizon, without deſcending: Therefore, &c.

Eud. By the ſame Reaſon, in the parallel Sphere, or under the Poles, there is a Day of ſix Months, and a Night likewiſe of ſix Months, or thereabouts. For the Day laſts as long as the Sun is above the Horizon; and the Night as long as the Sun is below it; but in the parallel Sphere, the Sun is ſix Months above the Horizon, and ſix Months under it; ſince it is ſix Months on this Side, and ſix on the other Side of the Equator, running through the Ecliptic in a Year, and ſince the Horizon is the Equator itſelf.

But, *Ariſtus*, what Method would you take, to know what Hour it is in any Countrey?

Ariſt. In one Hour the Sun makes 15 Degrees of his Circle by his daily Motion over the Equator, or parallel to the Equator; from Eaſt to Weſt. For he runs through the Circle in 24 Hours, and 24 Times 15 are 360. For which Cauſe, if it is Noon in the Meridian of *Paris*, it is an Hour after Noon in the Meridian 15 Degrees farther Eaſtward: There muſt have paſſed an Hour for the Sun's coming from that Meridian, to the Meridian of *Paris*. It is only eleven of the Clock in the Place 15 Degrees more Weſtward; there muſt be an Hour for the Sun's paſſing from the Meridian of *Paris*, into the Meridian of that Place. Two Hours after it is Noon in a Place 30 Degrees more Eaſtward, &c. 10 of the Clock in the Morning in a Place 30 Degrees more Weſtward. This being granted, all I have to do is to look upon a terreſtrial Globe for the Differences of Longitude, and knowing what Hour it is at *Paris*, I have the Difference of the Hours. I find, for Example, that when it is Noon in the Meridian of *Paris*, an Hour after it is Noon at *Vienna* in *Auſtria*, paſt three at *Hiſpahan*, ſeven in the Evening or thereabouts at *Pekin*, and Midnight in *New Zealand*: Since *Vienna* is a Place 15 Degrees more Weſtward, *Hiſpahan* 50, *Pekin* 110, and *New Zealand* 180; and becauſe 50 contains 15 more than three Times, 110 more than ſeven Times, and 180 more than 12 Times.

Eud. With the ſame Eaſe you will find Places that are Antipodes to one another.

Ariſt. I need only look in any Meridian for two Points 189 Degrees diſtant from one another. Thoſe two Points are Places that are Antipodes; for in a Word, the antipodal Parts of a terreſtrial Globe, are the two Points diametrically oppoſite. Now two Points of a Meridian, 180 Degrees diſtant from one another, are the Points diametrically oppoſite; ſince they are the two Extremities of the Diameter, which divides a Circle of 360 Degrees.

Eud. Theſe eaſie Perceptions will facilitate ſuch as more difficult. I have made a Diſcourſe

courſe upon the Earth, and the Minerals which it contains.

Ariſt. And this Evening I will return to your Cloſet, and will not leave you till you have imparted it to me.

CONVERSATION XIV.

Upon the Earth and Minerals.

Eud. I Promiſed you, *Ariſtus*, the Diſcourſe I have made upon the Earth and Minerals; here it is.

One may look upon the Earth as a pure Body without Mixture, or as a mix'd Body, whoſe Surface is the Habitation of Men and Animals.

The Earth, pure and without Mixture *, is a Body, whoſe Parts are ramoſe and very groſs;

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* The Word *Earth* among the Naturaliſts denotes the terraqueous Globe; and in Agriculture, ſignifies that compound Matter which ſerves for the Production and Growth of Vegetables planted therein; but the Chemical *Earth* differs widely from them both, as being a *perfectly homogeneous, or ſimple Body, hard, friable, inſoluble in Air or Water, fixed, and incapable of flowing in the Fire, but remaining immutable, and retaining its own Form and Quantity in them all.* We term it a Foſſil, as being exceedingly ſimple or inorganical, without any Diſtinction of Veſſels or Juices;

ramoſe, for whenever they are joined together, it is a Compound which has very much Conſiſtence, and ſhuts out the Paſſage of Light; very groſs, ſince Fire agitates and diſſolves them with great Difficulty.

The Earth, conſidered as a mix'd Body, is a Body of a round Figure, or thereabouts, vaſte, fertile, and containing different Beds of Clay, Chalk, Sand, and divers Minerals.

1. The Earth is phyſically round. Every conſiderable Portion of the Surface of the Earth cannot be an Arc of a Circle, without the Earth be of a round Figure. But every Portion of the Surface of the Earth is an Arc of a Circle. Go from South to North, or from North to South: You will ſee new Stars ariſe above the Horizon. If you advance 15 Degrees toward the Eaſt, the Sun riſes an Hour ſooner with Reſpect to you. Should you go 15 Degrees toward the Weſt, the Sun riſes an Hour later in Regard of you. When one

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Juices; and proceeding originally from the common Matter of the terraqueous Globe; 'tis called ſimple, becauſe all its Parts appear of the ſame Nature with the Whole: We define it hard, becauſe it reſiſts the Separation of its Parts; friable, becauſe it may be broke into leſs Maſſes, and fixed in the Fire, becauſe with whatever violent Degree of Heat it is every Way ſurrounded, it loſes nothing of its Weight or Bulk, yet without running into Glaſs; but poſſibly the Focus of a large burning Concave, may cauſe ſome alteration therein; though it would loſe conſiderably leſs than any other Body in Nature, even Gold itſelf; the moſt violent Fire being unable to break the Coheſion of its Parts, which is a very uncommon Property. 'Tis ſo ſimple, that though it enters into the Compoſition of all other Bodies, yet itſelf can never be reſolved into any different Subſtance. *Vide.Shaw's Chem.* 325.

leaves the Harbour of a Town, ſo as to ſail toward any Place whatever; one loſes the Sight of the Harbour, and then the Walls of the Town; and laſt of all the Top of the Towers. Let any one at that Inſtant go up upon the Scuttle of the Maſt, and he will immediately ſee again the Top of the Towers, then the Walls of the Town, and laſtly the Harbour. But theſe Objects diſappear again, as they did the firſt Time. Whence comes it, if not from this, that every conſiderable Portion of the Surface of the Earth is an Arc, the Middle of which being, in ſome Sort, elevated in Regard of you, with-holds from your Eyes, when you are at one of the Extremities of the Arc, that which would not be concealed from you, if you were at the other Extremity? In a Word, when the Earth, placed betwixt the Moon and the Sun, cauſes an Eclipſe of the Moon, as we ſhall mention hereafter, why is the Shadow formed like an Arch, which is ſpread over the Moon? Becauſe the Surface of the Earth, which projects this Shadow in Form of an Arch, is an Arch itſelf. Therefore the Earth is a round Body.

The Earth, I ſay, is nearly of a round Figure. 'Tis evident that it is not geometrically round, ſince one ſees upon its Surface Mountains whoſe Summits are loſt in the Clouds. But the Height of the higheſt Mountains is ſmaller in Regard of the Earth, than the Height of the ſmall Inequalities on an Orange-peel;

peel, in Regard to the Orange itſelf. The Height of a Mountain a League high, is contained almoſt 3000 Times in the Diameter of the Earth; for the Diameter of the Earth is about 2860 Leagues; ſince the Diameter of a Sphere is near a third Part of its Circumference, being as ſeven to 22; and the Earth is a Sphere whoſe Circumference is 9000 Leagues, as we ſhall ſee by and by. The Height of the ſmall Inequalities of an Orange, is it contained ſo many Times in the Diameter of the Orange?

Another Reaſon, which proves that the Earth is not perfectly round, is, becauſe according to the Trials of *M. Caſſini*, for determining the largeneſs of the Earth, its Surface ought to have the Figure of an Ellipſis † prolonged toward the Poles [ſ], and of which one Property is, that being divided into Degrees, every one of thoſe Degrees augments in Proportion as they approach the Poles; ſo that the Circumference of a Meridian of the Earth, ought to exceed the Circumference of its Equator about 54 Leagues [t]: But this Exceſs does not hinder but that the Earth may be phyſically round.

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† According to Sir *Iſaac Newton* the Figure of the Earth is an oblate Spheroid, it being every where higher in the Æquator, than in the Poles, conſequently its Poles muſt be depreſſed, and not prolonged. Aſtronomers have likewiſe obſerved the ſame of *Jupiter*, namely, that its Axis is ſhorter than its Æquatorial Diameter; for though this Planet be the greateſt of all the Planets, it is moved the ſwifteſt about its Axis, and therefore this Difference may be obſerved.

[ſ] Hiſt. de l'Acad. 1718. ſuite de l'année pag. 237, 238.

2. The Earth is a vaſte Body. A round Body, whoſe Circumference is 9000 Leagues, is a vaſte Body. The Earth is a round Body, whoſe Circumference is about 9000 Leagues. Every great Circle of the Earth has 360 Degrees; every Degree, according to *M. Piquart*, contains 25 Leagues of 2282 Fathoms, the Degrees of a Meridian, though unequal, contain almoſt ſo many, one with another, according to *M. Caſſini* himſelf [u]. In a Word, advance about 25 Leagues from South to North, the Pole appears to you elevated one Degree. Now 25 Leagues repeated 360 Times, are 9000 Leagues; multiply 360 by 25, the Product is 9000.

3. The Earth is a fertile Body, ſince it affords us Flowers in Spring, plentiful Harveſts in Summer, and Fruits in Autumn.

4. The Earth contains different Beds. In the Brink of great Rivers, and in Hills cut perpendicularly, you may often ſee a Bed of Clay, then one of Sand, one of Chalk, one of Stones, of Gravel, &c. Father *Merſenne* reports, that in making a Well at *Amſterdam*, they drew out ſucceſſively ſeven Foot of Clay, nine of Turf, ten of Potters-Clay, eight of Sand, four of Earth, ten of

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[t] Ibid.

[u] Pag. 247.

Potters-Sand; two of Potters-Clay, four of white Sand, one of Turf, fourteen of Sand mixed with Potters-Clay, four of Potters-Clay mixed with Sand, twelve of pure Potters-Clay, and thirty one of Sand [x].

Finally, the Earth contains in its Boſom divers Minerals, ſince they are drawn out of it. Therefore the Earth, conſidered as a mixed Body, is a Body round, or thereabouts, vaſt, fertile, and containing different Beds of divers Matters, divers Minerals.

They call Minerals the fat or lean Juices which are drawn out of the Earth, Metals and Stones.

1. Oil, Sulphur, Bitumen, Pitch, Amber, are of the firſt Sort of Juices. Common Salt, Mineral Salt, Vitriol, Allum, Nitre, Salt-Peter, Sal-Armoniac, *&c.* of the ſecond.

Oil is a Body whoſe Parts are ramoſe ‡, flexible, and impregnated with much ſubtile Matter;

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[x] *Bayle*, T. II. p. 279.

‡ By conſidering what has been ſaid concerning Attraction and Repulſion, we ſhall be better enabled to account for the Generality of chymical Experiments, than by imagining them to conſiſt of Particles hooked, pointed, blunted, *&c.* For Example, by Attraction we may eaſily underſtand why Quickſilver unites itſelf to Tin and Gold; and alſo why Water and Oil ſtick to Wood and clean Glaſs. We have Inſtances of Repulſion between Water and Oil, and generally between Water and all unctuous Bodies; between Mercury and Iron, as alſo between the Particles of any Duſt.

The Particles of any Salts attract one another with a very great Force, as appears by ſeveral Experiments: The following will be ſufficient to prove, that that Attraction exerts itſelf at a very ſmall Diſtance, and the repellent Force at a greater.

Matter. Hence Oil is diffuſed, clammy, fluid and eaſily inflamed.

Sulphur is an oily Body, whoſe ſmall Branches are ſhorter, more compact, and ſurrounded with ſubtile Matter. Hence Sulphur is neither ſoft, nor fluid, as pure Oil; but is very inflammable.

Bitumen is a Compound of Oil, Sulphur, terreſtrial and groſs Parts; accordingly Bitumen is hardened and inflammable like Sulphur, and oftentimes Water itſelf only renders it more hot; becauſe the groſſer Parts of the Bitumen being inflamed, repel the Water, and the Water which reſiſts hinders the Parts of the Bitumen from diſſipating preſently.

Pitch and Amber are Species of Bitumen. Pitch is a Bitumen which is immediately drawn from the Earth; and Amber a Bitumen which the Waves of the Sea throw upon the Coaſts, where it is hardened by Cold and Heat.

Common Salt is a Collection of long, ſtrait, ſtiff and ſharp Parts. In ſhort, it pricks, furniſhes

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Diſſolve Salt in Water, and when that Water is reduced into Vapour, the ſmall ſaline Particles will unite together and form greater Lumps; which proves the Attraction.

Theſe Particles are all equal, and of the ſame Figure: Whence it follows, that the leaſt Parts of which they are formed, had every where the ſame Situation in Reſpect to each other; that is, were every where diffuſed in the Water at equal Diſtances; which cannot be, unleſs they all repel one another with equal Forces. Confer Notes on CONVERS. IX. *Vide Newt. Opt. Que.* 31.

niſhes effectual Menſtruums, and preſerves Meats by penetrating them, contracting their Parts, and by that Means hindering the Action of the Air and ſubtile Matter from ſeparating and corrupting them. There are Mountains in *Poland* all full of Salt. They find Mines of it in *Caſtile.* In the Dukedom of *Cardonne* in *Spain*, there is a Mountain of Salt of all Colours [y]. Hence ſalt Waters.

But what Method do they uſe to draw Salt from the Sea? In Summer they make Choice of low Places, Pits. In thoſe Salt-Pits they raiſe Banks towards the Sea. When it is high Tide, they open Sluices to receive the Salt-Water into ſome Reſervoirs. After that they ſhut the Sluices, and let the Water evaporate, till there remain but ſo much as is neceſſary for keeping the Salt in a certain Agitation. When the Water is prepared after this Manner, they make it run into ſmall Channels, much like the Walks of a Parterre, and whoſe Ground is Potter's Earth, which imbibes no Water [z].

Mineral Salt is a foſſile Salt, tranſparent, and harder than Sea Salt.

Vitriol is a Mixture of Sulphur, an acid or ſharp and pointed Salt, Phlegm, Earth, Iron, and Copper: For 1. Sometimes a ſulphureous Odour is exhaled from it [a]. 2. If you put Vitriol into a crucible, and thruſt it into the Fire, you have a ſharp and pointed Salt drenched in Phlegm, and this is what they call Spirit of Vitriol. 3. Spirit of Vitriol being poured upon Iron, whoſe Sulphur it corrodes, is reincorporated with Vitriol. 4. Chymiſts draw from it Earth and ferruginous Particles. 5. Iron being put into a Solution of Vitriol, is charged and ſtriated with Particles of Copper. Father *Kircher* ſpeaks of vitrioline Waters, in which Plates of Iron ſeem to be changed into Copper, the Parts of the Copper taking the Place of thoſe of Iron, without any real Tranſmutation *. Rub a Plate of Steel with Particles of blue Vitriol wetted: The Particles of Copper are fixed in the Pores of the Surface of the Steel, and you would ſay that the Steel is changed all of a ſudden into Copper.

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[y] Bib. univ. & hiſt. 1691.

[z] Regis T. 2. p. 205.

[a] Mem. de l'Acad. 1713. p. 174.

Allum differs little from Vitriol, except that the Spirit of Allum is ſharper; whence it comes to paſs, that the Acid of Allum is leſs agreeable.

Allum, Vitriol and Sea Salt, however pure they be already, afford a ſaline and oily Liquor, and depoſite a very fine Earth [b].

Nitre is a different Acid, contained in a volatile Salt; and Salt-Peter is the ſame Acid, ſtrongly engaged in a fixed Salt, according to the chymical Obſervation of *M. Lemery* [c]. Ni-

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* Kirker de M. ſub, p. 321.

[b] Mem. de l'Acad. 1713. p. 32.

[c] Ibid.

tre becomes Salt-Peter by the Mixture of a foreign fixed Salt [d]. The fixed Salt of Aſhes caſt upon the Dung of Animals afford Salt-Peter. Salt-Peter is a Salt whoſe Surface is more rugged than common Salt. Accordingly, 1. Salt-Peter is melted more eaſily, becauſe the Inequality of its Parts receives the Action of the Water more eaſily. 2. The Salt-Peter is more light, becauſe having a more unequal Surface, it is more porous. Salt-Peter fuſes and gives a Force to the Flame, becauſe it has ſolid Parts which are divided ſucceſſively, and bound with Violence every Way. They gather it up upon the Sides of the Walls of Caves, like a ſort of ſalt Flower. The beſt comes from the *Eaſt-Indies.* Throughout all *Europe* they draw much of it from old Plaiſter, from the Earth of Church-yards, from Pigeon-Houſes, Stables [e], and from Plants; and as it is drawn from Plants which ſometimes one ſees fuſe in Fire, and from the Dung of Animals where it ſeems to be brought to Perfection, it may paſs for a vegetable and animal Salt, as well as for a mineral Salt. In ſhort, they find Mines of Sulphur, common Salt, mineral Salt, Vitriol and Allum: But there are none of Salt-Peter to be found [f].

Sal Armoniac is a volatile Salt, urinous, and penetrated by an Acid, which cuts, divides and corrodes. Put one Part of common Salt upon five of Urine; add half the Quantity of Soot: From this Mixture is ſublimated a rarified Subſtance, white like Meal, lightly ſticking together, and friable; and this is artificial Sal-Armoniac[g]. Earths naturally loaded with common Salt, impregnated with the Urine of ſeveral Animals, and expoſed to the Heat of the Sun, ſeem capable of furniſhing a natural Sal-Armoniac.

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[d] Ibid. 1717. p. 127.

[e] Hiſt. de l'Acad. 1717. p. 29.

[f] Ibid.

As for Salt of Tartar, it is an acid Salt drawn from Tartar; and the Tartar is the Lees of Wine ſticking to the internal Surface of Caſks.

But finally, what is the moſt probable Origin of thoſe terreſtrial, oily or ſaltiſh Juices?

1. It is certain that the Earth is penetrated by a fine Matter agitated without Intermiſſion: For there happen inceſſantly Changes in the Boſom of the Earth; Exhalations iſſue out of it in the deepeſt Mines; the Mines of Stones and Metals being exhauſted, are filled again with Stones and Metals. Theſe Changes do not happen without the Tranſportation and Agitation of the Parts. Now, from what does this Tranſportation and Agitation immediately proceed, if not from the ſubtile Matter, conſtantly agitated, and what penetrates the Earth?

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[g] Ibid. 1716. p. 29.

2. The Parts of the Earth being ſolid and irregular, there muſt be between them an infinite Number of Interſtices of different Figures.

3. An Infinity of Particles of Matter driven into thoſe Interſtices, as into ſo many Moulds, by the Action of the ſubtile Matter, ought therein to take different Figures. Thoſe Particles coming in the End to encounter and grapple with one another, compoſe divers Corpuſcles, long, ſhort, hard, flexible, ſmooth, rugged, blunt, ſharp, or pointed. Such probably is the Original of terreſtrial Juices, Oils, Sulphurs, and Salts; and from the Mixture of thoſe Juices proceed Metals and Stones.

2. They call Metals Bodies that are ſolid, hard, capable of melting, and malleable; a Quality which diſtinguiſhes them from Stones. Divers Mixtures of long and ramoſe Parts, of Oil, Sulphur, Salt and Earth, make divers Metals; Tin, Iron, Copper, Silver, Lead and Gold. For 1. With Sulphur, Vitriol and Earth, they make a Species of artificial Iron. 2. From moſt Metals they draw Parts of Oil, Sulphur, Salt or Earth. 3. Why do Metals melt, and lengthen by a Wiredrawing Iron, or at leaſt under the Hammer? Becauſe their long and ramoſe Parts run upon one another without quitting their Hold. Different Exhalations, oily, ſulphurous, ſaltiſh, and earthy, being raiſed up by the Action of the ſubtile Matter, and mixed toward the Surface of the Earth,

make therein metalline Veins, from which they draw divers Metals.

The Gravity of Metals is very unequal. Tin affords 532 Pounds in one cubical Foot, Iron 576, Copper 648, Silver 744, Lead 828, and Gold 1368.

Tin contains ſulphurous Parts, ſince it is inflamed with Salt-Peter; ramoſe and flexible, for it melts, and eaſily yields to the Hammer; conſiderably diſtant from each other; in a Word, it weighs leſs than other Metals.

Iron is a Compound of Sulphur, vitrioline Salt, and Earth. Did not *M. Geofroy* make Iron by a Mixture of theſe three Principles? At leaſt he made a Powder, black, heavy, and cleaving to the Loadſtone; a ſpecifical Mark of Iron[h]. Its Parts are ſtiff and groſs: Accordingly it yields with Difficulty, whether to the Fire, or to the Hammer. But they are conſiderably diſtant from one another, for it is lighter than the moſt Part of other Metals; and of the Number of thoſe which are moſt eaſily diſſolved by *Aqua Fortis*. There is hardly any Countrey in the World, eſpecially towards the Poles, where Nature does not produce Iron. They draw it from the *Argilla*[i], and from an infinite Number of Foſſils. How many mineral Fountains are impregnated with it? They find it in the Aſhes of Plants. *M.*

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[h] Hiſt. de l'Acad. 1704. p. 39. Journ. des Sçavans, 1719. p. 378.

[i] *Zanichelli.* De ferro.

Geofroy examining with a Knife, touched by a Loadſtone, the Aſhes of a Vine Branch, of Herbs, and of Wood, exactly reduced to Lye-Aſhes, always found Parcels of Iron, and he eſteemed it as a Thing impoſſible to make Aſhes without making Iron alſo[k]. Did not the Royal Society of *London* ſee Grains of Iron drawn from an humane Stone, calcined by Dr. *Liſter*[l]? Probably thoſe Particles paſs from the Vegetables into the Animals themſelves.

Steel is only refined Iron. According to the Experiments of *M. Reaumur*[m], the moſt proper Compoſition for converting into the hardeſt, fineſt, and beſt Steel, Irons fitteſt for becoming Steel, conſiſts in two Parts of Soot, one Part of beaten Coal, one Part of Aſhes, and about threeFourths of a Part of Sea Salt, or ſomething leſs. If you uſe ſixteen Pounds of Soot, you muſt uſe eight of Coal, eight of Aſhes, and ſix or five only of Sea Salt.

There muſt be a leſs active Compoſition for other Irons; two Parts of Aſhes, one of Soot, one of Coal, three Fourths of a Part of Sea Salt, or thereabout.

This laſt Compoſition may be uſed with Succeſs upon the Iron of the firſt Species; but the Operation thereof is ſlower and longer. The Soot, Coal, Aſhes, and Salt require ſome Preparation. They make the Soot paſs thro' a groſs Searce, or through a ſort of Sieve. The finer it is, it will be ſo much the more effectual. The Coal is pounded; after that it is made to paſs through a Searce moderately fine. The Aſhes are good, provided they are of new Wood: They make them alſo paſs, like the Coal, through a Sieve. As for the Sea Salt, it is reduced into a very fine Powder.

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[k] Hiſt. de l'Acad. 1705, p. 65. [l] Journ: des Sçav. 1719. p. 378. [m] L'Art de convertir le Fer en Acier.

The Mixture of Soot, Coal, Aſhes and Salt, is well made, when the Matter appears to be of the ſame Colour, in whatever Part one looks on it.

Laſtly, they ſurround Bars of Iron with this Mixture; plaiſter the Whole over with Potter's Earth, and put it into a Stove over a violent Fire. In the Violence of the Agitation, the Particles of the Mixture, the Salts penetrate the Iron, comminute the Parts of it, drive out the earthy Matter which is not ſufficiently wrought by Nature, fill up its Interſtices, and bind its Parts together. Hence proceed the Fineneſs, the Flexibility, and the Hardneſs of the Metal; and this is Steel. Cymeters have been made of Steel, ſo fine and hard, that they cut Bars of Iron without being blunted.

Iron melted, but quickly cooled again, is changed into hard and brittle Steel; hard, becauſe the Particles are cloſely united; brittle, becauſe the ſmall Globules of the Steel only touch one another by ſpherical Surfaces.

M. Zanichelli thinks that Iron contains a little Mercury. Preſent, ſays he, a Piece of poliſhed Iron to Mercury, at the Diſtance of two Fingers Breadth, the Mercury flies to the Iron, and covers its Surface[n].

Copper is compounded of more compact Parts than thoſe of Iron, and of a Salt ſharp and fixed; for which Reaſon Copper is more weighty than Iron; it is melted with greater Difficulty, and its Salt is proper for corroding of Fleſh.

Silver has its Parts more compact and leſs porous than Copper; for which Reaſon it is heavier.

Lead is a Tiſſue of Parts more equal, more flexible, leſs ramoſe, and leſs ſeparated; accordingly Lead is divided, bent and melted quicker, and is more ponderous.

Gold differs from Silver and Lead, in that it reſults from Parts which are at the ſame Time more groſs, more ramoſe, more united, and leſs porous. Hence Gold is heated and melted with Difficulty; it is the heavieſt of Metals, and may be drawn out almoſt to an infinite Length.

There are Minerals, which are not properly Metals, not being malleable; but which are notwithſtanding Metalline, by Reaſon of the Parts which they contain; Antimony, for Example, in the Analyſis which is made of it, appears to be but a metalline Subſtance, mixed with a good deal of very volatile Sulphur, and a kind of acid Salt; whence Antimony cauſes vomiting. Quickſilver, which alſo contains ſomething metalline, is a Body compounded of round, poliſhed and ſlippery Parts, whoſe Pores allow a Paſſage only to the ſubtile Matter: For which Reaſon Quickſilver is fluid, and its Drops are formed round, becauſe the Air which cannot penetrate them, by Reaſon of the Smalneſs of their Pores, thruſts them towards a common Center, until they equally reſiſt it on all Sides under a ſpherical Surface. Laſtly, native Cinnabar is a Mixture of Quickſilver and Sulphur; in a Word, Art produces one very like it from Sulphur and Quickſilver.

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[n] Journ. des Sçav. 1719. p. 376.

It is of ſome Importance to know by what Marks one may diſcern the Places where Nature conceals her Treaſures. Oftentimes ſhe ſeems to lay Snares for the Curioſity and Covetouſneſs of Men, who being deceived by fine Appearances, open the Boſom of the Earth without Succeſs. We have ſeen it opened near *Paris* with very conſiderable, but very uſeleſs Expences. But thoſe Places of the Earth that appear burnt, protuberant and mixed with white Rocks like Sorts of Cryſtals, rarely deceive. Theſe are Signs almoſt infallible of an abundance of Mines. Copper is diſcovered ſometimes by the Verdigreaſe which it throws out from the Earth [o].

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[o] Mem. de Trevoux. Sept. 1704. p. 1621.

3. Stones do not differ from Metals, but in having their Parts leſs ramoſe, leſs interwoven, and conſequently leſs proper for being melted, or extended under the Hammer. At leaſt it is certain that there are Stones formed of Sulphur and Earth, ſince there are Flints which being rubbed againſt one another, ſend forth a ſulphurous Smell. They diſtinguiſh two Sorts of Stones, common Stones and precious Stones.

There are ſome Stones formed of Chalk, and others of a fluid Matter, or of a ſoft Paſte which dries and hardens. 1. There are ſome formed of Chalk, whoſe Parts are probably linked together by certain Sulphurs; for Stones are found in Quarries, where ſome Years before one found only Chalk, and the Stones are different according to the Diverſity of Chalks. 2. There are ſome formed of a fluid Matter, or of a ſoft Paſte. Stones cannot contain foreign Bodies within them, unleſs they entered when they were a fluid Matter, or at leaſt a ſoft Paſte. But there are continually found in ſome Stones, Leaves, Plants, Inſects, Bones of terreſtrial Animals, and of Men, yea whole Skeletons [p], Fiſhes and Shells. Therefore, *&c.*

The Shells which are found in the Generality of Quarries, ſeem to prove that the Surface of the terreſtrial Globe has been Mud and Mire drenched with the Water of the Sea, at leaſt to a certain Depth. Therefore the Water of the Sea has covered the whole Earth; and thence probably it is that the Shelves or Beds of Stones, which are found in the Plains, are ordinarily horizontal, and parallel amongſt themſelves.

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[p] Hiſt. de l'Acad. 1716. p. 15. 1706. p. 10.

When the Petrification of the ſame Maſs has not been continued, but that one Part of it was done in a certain Time, and another Part in another Time, the Stone appears diſpoſed in Form of Beds, like the Trunk of a Tree whoſe Accretion is interrupted in Winter.

The Variety of Stones proceeds from the Diverſity of Mixtures. For Example, if ſome Oil happen to unite the Grains of Sand, it is brown Free-Stone. If the Parts of Salt and Oil, whoſe irregular Texture would make Sand, are united in ſuch Manner that a Maſs reſults from them whoſe Pores are direct, and leave a free Paſſage every Way for the Light, it is Cryſtal. In a Word, Cryſtal may be calcined like Free-ſtone. Are the Parts fit for compoſing Cryſtal more ſtraitly united? It is Diamond. Some Parts of Metal in Compoſitions, which without this Mixture would make Diamonds, render the Compoſitions leſs hard, and make Colours to appear in them; and theſe are Agates, Emralds, Topazes, Rubies and Sapphires.

There are Stones formed even of Wood itſelf[q]. Wood is petrified, when Particles of

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[q] Jour. des Sçav. 3. Feb. 1693.

Sand, Chalk, Stones or Salt, inſinuate themſelves and ſink into the Pores of the Wood, and are there faſtened to one another. And if thoſe ſmall Parts are faſtened by certain Mixtures of Sulphur, there is Metal formed in the Wood itſelf. They have found in petrified Wood a Vein of Metal, red and very fine. But a much more aſtoniſhing Petrification is that which Father *Kirker* mentions of a whole Village in *Africa* turned into Stone, with all that was in it, even to the Inhabitants themſelves[r]. For ſuch an Event the Earth of that Countrey muſt needs have emitted a ſtrange Quantity of Salt, to be capable of penetrating divers Bodies and there fixing themſelves. The Fact might have appeared more marvellous, had it been leſs ſo. And if it were not too ſurprizing not to be ſuſpected, there would be no greater Difficulty in believing what *Acoſta* ſays of a Company of *Spaniſh* Cavaliers turned into Stones.

However that be, the Sea has its Stones. The *Galets* are Flints ordinarily round, and always poliſhed, which the Sea throws upon the Coaſts. Whence proceeds their round Figure, and their Smoothneſs? From their having been a long Time agitated by the Waves and worn againſt one another.

One would ſcarcely believe that Worms gnaw Stones. Nevertheleſs a Virtuoſo, who found

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[r] Mund. Subt. T. II. L. VIII. Sec. 2. p. 50.

Worms in a gnawed Stone, ſhut them up in a Box with ſome Pieces of the Stone; and eight Days after he found the Pieces ſenſibly gnawed.

Thoſe ſmall Inſects eat ſolid Bodies ſo much the more eaſily, as having a ſort of Needles, very hard and ſharp, they inſert them more eaſily into the Interſtices of Stones.

Will you ſubjoin nothing to this Diſcourſe, *Ariſtus*?

Ariſt. I thought as you proceeded I ſaw the Hand of Nature forming precious Stones: But *M. Geofroy*'s Syſtem [a] upon the Origin of Stones has appeared to me very ſimple; here it is, I think, in few Words. Earth without Mixture is the only neceſſary Ground for Petrifactions. There are two Sorts of primitive Parts in the Earth; the one which are very fine *Laminæ*, and almoſt equal among themſelves, and the other which have all Sorts of irregular Figures. The firſt being united in a ſufficient Quantity make a homogeneous Body, very hard by Reaſon of the immediate Contact of the Parts, and tranſparent becauſe of their regular Diſpoſition, which leaves free Paſſages every Way for the Light; and this is Cryſtal. The other, leſs ſuſceptible of immediate Contact, and a regular Diſpoſition, only form opake and leſs hard Collections. Cryſtals are only formed of the firſt; others are formed both of the firſt and ſecond; the firſt are a ſtony cryſtalline Juice; Water, as one may obſerve from ſome ſtony Fountains, which incruſt with Stone the Pipes through which they flow, is a proper Vehicle for carrying this Juice; this Juice is more weighty and fixed than Water, and is never evaporated with it.

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[a] Hiſt. de l'Acad. 1716. p. 8.

This being granted, after what Manner is natural Cryſtal formed? Much after the ſame Manner as ſaline Cryſtals in Chymiſtry. A Water charged with Salt is evaporated ſlowly in a cool Place; the Salts which were too much ſeparated, approach one another in the Evaporation; the Slowneſs of the Evaporation affords them, in their approaching one another ſlowly, Leiſure for aſſuming, without Confuſion, ſuch an Arrangement as is fit; the Cold which diminiſhes the Agitation of the Water ſlowly, contributes to the two Effects; hence chymical Cryſtals. Water charged with cryſtalline Juice, fallen through the Clefts of a Rock to the Bottom, has permitted the Particles of the cryſtalline Juice to approach one another in the ſlow Evaporation; and this is Rock-cryſtal.

Cryſtal is not formed univerſally alike, becauſe the cryſtalline Juice is unequally diffuſed. If Water charged with this Juice, paſſing thro' a Portion of Earth, bind the Parts of it together, and be evaporated, the Compound hardens into common Stone. The Stone approaches more or leſs to Cryſtal, according to the Quantity of cryſtalline Juice; and it is of a finer Grain, according as the *Moleculæ* of Earth are more homogeneous and ſmaller; hence Marble. Finally, divers Mixtures of cryſtalline Juice and groſs Parts make different Stones, Flints, Agates, *&c.*

Eud. The Hypotheſis is ingenious, and I love to ſee you form Marble, Cryſtals, Agates, and precious Stones, after *M. Geoffroy*, in ſo ſimple a Manner. But there is no Stone that ſtrikes me ſo much as the Loadſtone.

Ariſt. You will teach me the Original of the Magnetic Virtue. I will endeavour to explain the Effects of it, after you have diſcourſed of the vulnerary Stone, which you omitted; 'tis true it is only an artificial one, but efficacious enough to deſerve ſome Regard.

Eud. Let us confine our ſelves then to the ſimple vulnerary Stone. " As for the ſimple " vulnerary Stone, *ſays M. Geofroy* [t], they take " equal Parts of the Filings of Iron, and of " pulverized Tartar, they make them in" to a ſoft Paſte with Wine or *Aqua Vitæ*, " and leave the Matter in Digeſtion before " the Sun in the Summer, moving it from " Time to Time, until the Whole be dried up " intirely. They reduce the Maſs into Pow" der, and after that ſoak it in Wine, making " it digeſt again, and then dry it. They re" peat theſe Operations until they perceive no " more Grains of Filings, and the Whole be

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[t] Mem. de l'Acad. 1713. p. 187.

“ reduced into a very fine Powder. Then with *Aqua Vitæ* they form Balls of it, which they leave to dry in the Air, and to harden; this is the ſimple vulnerary Stone, whoſe ſingular Virtues they boaſt ſo much of for healing Wounds and Ulcers.

“ They ſoak this Stone in Wine for ſome Time, or in *Aqua Vitæ* or Urine; and with this Diſſolution they waſh ſimple Wounds, or elſe ſyringe them inwardly; ſometimes they ſpread the Stone itſelf upon the Wound reduced into Powder to ſtop Hemorrhages, and apply Compreſſes ſoaked in the ſame Solution upon it, which they renew once in twenty four Hours. They do the ſame Thing for Ulcers, which it dries up and cicatrizes quickly.

Let us now, *Ariſtus*, only think of unveiling the Myſteries of the Loadſtone, if poſſible.

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CONVERSATION XV.

Upon the Loadſtone.

Ariſt. TILL you have diſcovered to me the Myſteries of the Loadſtone, I ſhall be no more at Quiet than a Loadſtone itſelf, which is not in its natural Situation, and which is ſeeking out the Poles of the Earth.

Eud. The Loadſtone, that Mineral, whoſe Direction guides us without erring through unknown Ways even to the End of the World, and brings us home again loaded with the Stones of the Eaſt, and with the Gold of *Peru*, is nothing elſe, at leaſt ordinarily, but a blackiſh and ferruginous Stone, which is found in Iron Mines, but harder than Iron itſelf. A certain Author [u] makes Mention of a white Loadſtone, and that it is as ſtrong as the beſt; but a white Loadſtone is very rare.

Certainly this ſort of Stone has aſtoniſhing Properties, and much more capable of ſtriking a Philoſopher than Gold, precious Stones and Diamonds; namely the Direction, magnetic Vortex, Attraction, Communication, Inclination and Declenſion.

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[u] *Velſchius*, J. des Sçav. 29 *Mar.* 1677. p. 80.

A Load-

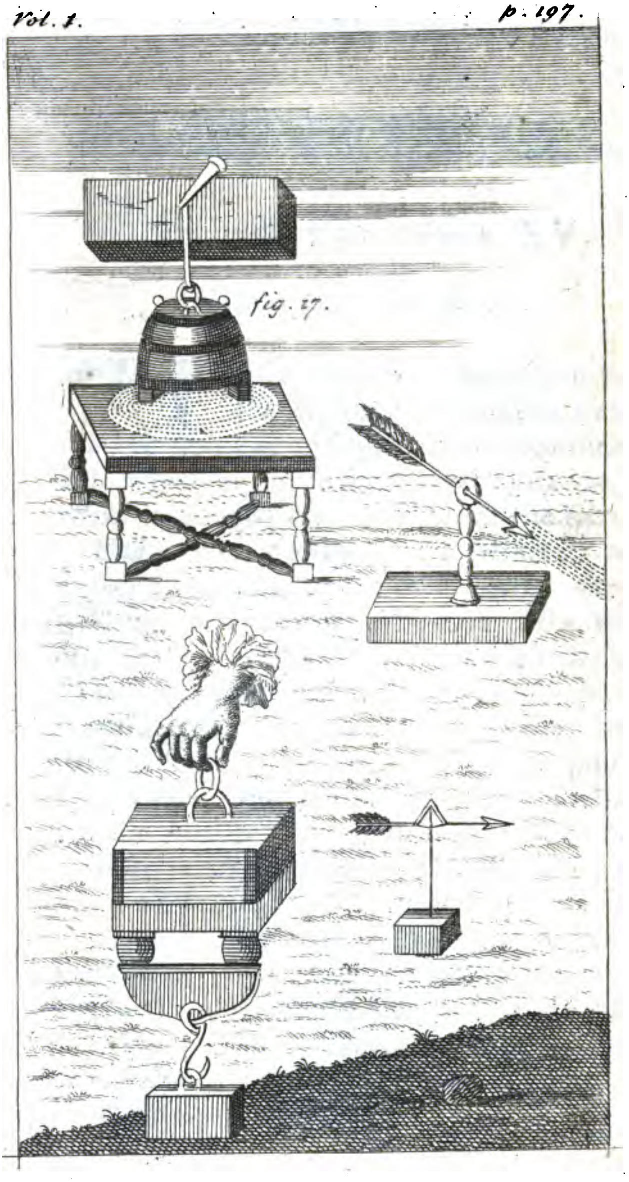

fig. 17.

A Loadſtone at Liberty and ſuſpended by a Thread, ſeems to affect to turn always the ſame Sides toward the ſame Poles of the Earth; and this is what they call the Direction of the Loadſtone. An imperceptible Matter inceſſantly circulates round it, iſſuing out of one of its oppoſite Sides, and entering again thro' the other, and leaving Traces, which repreſent its circular Motion, in the Filings of Steel or Iron ſcattered upon Paper, which they bring near it; this is the magnetic Vortex, *Fig.* 17. You know they call a Vortex ſome liquid Matter which circulates round about a ſpherical Body. The Loadſtone, Iron and Steel being free and placed at a certain Diſtance, are attached to the Loadſtone as of themſelves; this is Attraction. They ſay that there is in the *Muſeum* of the Royal Society at *London*, a Loadſtone which attracts a Needle at nine Foot Diſtance*. In the very Moment of this marvellous Union the Loadſtone makes its properties paſs at once into the Iron and Steel, into the Blade of a Knife, and the Needle of a Mariner's Compaſs; this is Communication. Should it approach to a Pole of the Earth, the Side which is neareſt the Pole is biaſs'd and inclines toward the Earth; this is Inclination. Inclination is remarkably ſenſible in a Needle touched with the Loadſtone. Finally, the Direction of the Loadſtone, and of Bodies touched with it, towards the Poles of the Earth is not ſo fixed but that they decline ſome Degrees towards the Eaſt, or towards the Weſt; and this is the Declination of the Loadſtone.

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* Jour. des Sçav. 22 *Mar*. 1682. p. 79.

Ariſt. I am well apprized of theſe Wonders, neither am I weary of admiring them; but what is their Original, or what is the phyſical Cauſe, whoſe Action produces them? Upon this Head one has ſome Difficulty to explain one's ſelf clearly.

Eud. It is a ſort of ſubtile Matter, which running from one Pole of the Earth toward the other, penetrates the Loadſtone and Bodies touched with it.

1. It is a ſort of ſubtile Matter. For it is not the Loadſtone; the Wonders of the Loadſtone conſiſt in divers Motions of the Loadſtone itſelf, of Iron and Steel; and the Loadſtone is not moved of itſelf, being only ineffectual Matter which does not properly move the Iron or Steel but they come in Search of it, even when it is immovable. What is then this Source of philoſophical Prodigies? It muſt be agitated Matter, but imperceptible. It is, I ſay, agitated Matter, ſince it produces Motions of inanimate Bodies, Motions which depend upon the Stroke upon ſome Matter; it is imperceptible Matter; it does not affect the Senſes. Now this imperceptible Matter is a ſort of a ſubtile Matter, or only the Air. It is not merely the Air; the Air does not affect to

unite two Loadſtones. Have they loſt their Vortex in the Fire? It is certain that the Air does not unite them. Therefore it is a more refined Matter, a ſort of ſubtile Matter.

2. This Matter flows near the Surface of the Earth from one Pole toward the other: Being agitated as it is, it cannot have a Direction from Pole to Pole without flowing after that Manner. But it has a Direction from Pole to Pole; for it gives ſuch a Direction to the Loadſtone being at Liberty, and *M. de la Hire* having encloſed in a Stone ſome conſiderably fine Iron Wires, and Parallel to the Axis of the Earth, or placed in the Plane of the Meridian, at the End of ten Years found, that the Matter which animates the Loadſtone, flowed from one End to the other of thoſe Wires[y].

3. Laſtly, this Matter penetrates the Loadſtone. Preſent to a Loadſtone a light Bed of Filings of Iron or Steel, ſcattered upon ſome Paper. Immediately a Vortex of Filings ſeems to iſſue out from the two oppoſite Sides of the Loadſtone; a Vortex which cannot be formed but by a Vortex of ſubtile Matter that iſſues out of the Loadſtone.

The ſurprizing Effects then of the Loadſtone proceed from a ſort of ſubtile Matter, which flowing from one Pole of the Earth toward the other, penetrates the Loadſtone and Bodies touched with it. Which was to be proved.

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[y] Hiſt. de l'Acad. 1705. p. 7.

But in Order to comprehend the Mechaniſm of this Matter, which they call magnetic Matter, let us make ſome Obſervations.

1. The Matter, which directs the two Extremities of the Loadſtone toward the two Poles of the Earth, flows inceſſantly and rapidly from the one to the other of thoſe Extremities; as one may obſerve by the Velocity with which it forms the Vortex of File Duſt. Therefore there muſt be in the internal Part of the Earth a Fluid of the like Nature, which flowing from Pole to Pole makes itſelf free Paſſages in the Loadſtone, while it is forming in an Iron Mine.

2. The magnetic Matter that iſſues out rapidly from one Extremity of the Loadſtone, and is, no doubt, reflected by the Reſiſtance of the Air, which increaſes in Proportion to the Velocity of the Matter that ſtrikes it, circulates upon the Surface of the Loadſtone: Why ſhould not the Matter which is united toward a Pole of the Earth, and darted out into the Air, be reflected after the ſame Manner by the Reſiſtance of the Air, and forced to return by circulating near both the internal and external Surface of the Earth? Thus you have a Vortex of magnetic Matter round about the Earth, as well as about the Loadſtone.

3. Can one be aſtoniſhed after this, that they look upon the Earth as a great Loadſtone,

and upon the Loadſtone as a little Earth, which has its Poles, Axis, Meridian and Equator?

Therefore they diſtinguiſh two Poles in the Loadſtone, a South or meridional one, and a North or ſeptentrional one. Thoſe two Poles are the two Sides of the Loadſtone, which turn as of themſelves toward the Poles of the Earth. The Pole, which in the Mine lay Southward, is the meridional Pole; and that which faced the North, is the Septentrional.

4. If the Matter which circulates round about the Loadſtone, could enter again by the Pole which permits it to iſſue out, it would not circulate. Conſequently the ſame Parts of magnetic Matter do not find Acceſs into a Loadſtone but by the ſame Pole. Do they enter by the meridional Pole? They cannot enter by the Septentrional. If they enter by the ſeptentrional Pole, they cannot enter by the Meridional. For which Reaſon a Loadſtone ſuſpended over the Surface of the Earth, cannot receive directly the Matter which paſſed through it in the Mine, and which returns by circulating, without being in an oppoſite Situation. Did its meridional Pole receive Matter coming from the South? It ought to face the North in order to receive the ſame Matter on its Return. Hence the Pole which points to the North, is called the meridional Pole of the Loadſtone, and the oppoſite Pole is called the Septentrional.

5. The Pores of the Earth and Loadſtone ought to have a particular Configuration, ſince they do not receive the ſame magnetic Matter but only by one Part, neither does it produce the ſame Effects in all Bodies. Has not the magnetic Matter itſelf its own Configuration?

M. Huygens conceived its Particles to be like ſo many Darts, and the Pores of the Loadſtone like ſmall Pipes, whoſe internal Surfaces was beſtrewed with ſmall flexible Hairs, inclining to one Side for letting the Fluid run, but always ready to reſiſt and hinder its returning by the ſame Way: *M. Deſcartes* conceived thoſe Particles as ſo many Screws turned round contrary Ways, and the Pores as ſo many Screw-Boxes formed in an oppoſite Manner, and fit for letting the Fluid run; the one only from South to North, and the other only from North to South. The firſt Opinion appears more ſimple, and the ſecond more ingenious. But as a Thouſand different Configurations of Parts and Pores may cauſe a magnetic Vortex, one can determine nothing upon this Head.

6. Does the magnetic Matter come from both Poles of the Earth, into both Poles of the Loadſtone? *M. Deſcartes* believed it; and there is no ſolid Reaſon to prove the contrary. If the Matter did not come from both Poles, Bodies thrown upward under the Equator, being thruſt more toward one Pole than the other,

ther, would they fall perpendicularly? A Loadſtone being at Liberty, would it not be carried away by the Torrent of this Matter?

Ariſt. There ſeems to be nothing more needful to explain the Experiments of the Loadſtone.

Eud. Well! I am going to make ſome very curious ones; you ſhall explain them.

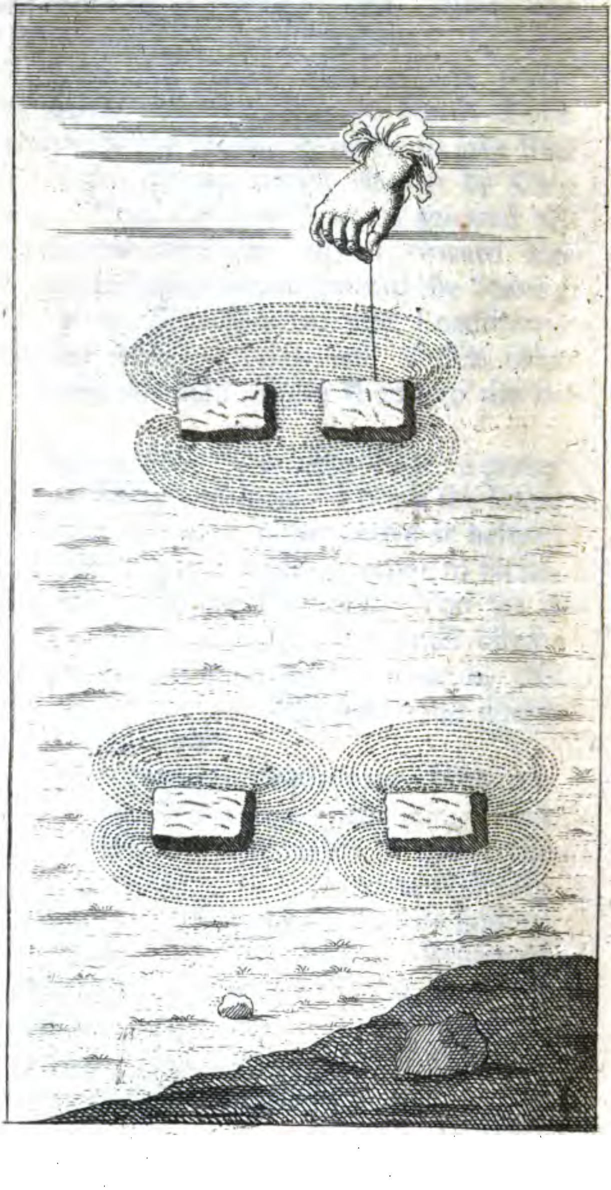
In the firſt Place I hang up an excellent Loadſtone by a Thread perpendicular to its Axis.——It is agitated, and appears reſtleſs, until its South Pole be turned toward the North, and its North Pole toward the South.

Ariſt. The fine Matter which flows rapidly from one Pole of the Earth towards the other, and which at firſt does not find in the Stone the Pole appointed to receive it, following its Direction, attempts in vain to enter, ſtrikes, and thruſts irregularly. The Stone being ſtruck and thruſt in that Sort, yields to the Strokes according to their Force. Hence, this Agitation, and a kind of Reſtleſſneſs. By Virtue of its being agitated in turning about, it preſents at laſt to the Direction of the magnetic Matter the Pole deſtined for receiving it, and which did receive it in the Boſom of the Earth. The Matter finds therein a free Acceſs, flows into it, penetrates the Stone, and paſſes through without puſhing it more to one Side than another; and the Loadſtone remains immovable; no more Reſtleſsneſs. Draw it out of this Situation: Its firſt Reſtleſsneſs is renewed ed and ceaſes by the ſame Reaſon. Now, the meridional Pole of the Loadſtone, or that which faced the South when it was within the Earth, ought to face the North above the Surface of the Earth, in order to give free Acceſs to the Matter which returns by Circulation. Thus the Loadſtone is agitated till its meridional Pole be turned toward the North, and its Septentrional toward the South; and this is the Direction of the Loadſtone; a Direction which guides our Veſſels over Rocks, from one End of the World to the other.

Eud. Let us now ſtrew upon Paper a pretty thin Bed of Filings of Iron. I bring the Stone near it perpendicularly, either above or below; I agitate the Paper a little in order to facilitate the Action of the File-duſt. You ſee it at once divided, as of itſelf, into ſmall circular Threads which ſeem to iſſue out of the Poles of the Stone, and diſpoſed round about it in Form of a Vortex.

Ariſt. The magnetic Matter that iſſues out of the Pole, and is reflected by the Air, which encounters it directly, and reſiſts ſo much the more as it is ſtruck with the greater Velocity by the Matter united in the Pole, not finding Acceſs to enter by the ſame Pole, by Reaſon of the Matter which comes inceſſantly, and the Configuration of the Pores, is divided into concentral Semicircles, ſome of them ſtronger, and others weaker, ſeparated a little by the Oppoſi-

Vol. 1. *p. 205.*



Oppoſition of the Air; and circulating upon the Surface of the Loadſtone in Form of a Vortex, it comes in Queſt of the Pole, which received it at firſt in its Way. It finds the Filings of Iron, penetrates them, and lays them along, becauſe it flows in them more eaſily than in the Air, by Reaſon that the Pores of the Iron are more proportioned to the Configuration of its Parts, more ſolid, and leſs interrupted than the Interſtices of the Air inceſſantly agitated with an univerſal Motion. Thus it deſcribes the Figure of its Vortex; and the Eye being ſurprized, ſees in the File-duſt a Vortex formed all at once.

Eud. To the South Pole of this Loadſtone ſuſpended, I preſent the North Pole of another Loadſtone which is free. The one attracts the other; and you would ſay that an agreeable Sympathy united them both.

Ariſt. In this Situation the Matter, which is darted out from one of the Loadſtones, finds a free Acceſs into the other, and is carried thither with extreme Velocity, driving out the Air from between the Loadſtones. There is no more *Equilibrium*. The Air being driven out retires, and is contracted behind the Loadſtones; being contracted it is dilated. In its being dilated, it puſhes the Loadſtones towards one another. The Loadſtones being puſhed, the one towards the other by oppoſite Forces, and finding leſs Force to overcome inwardly than outwardly, becauſe there is nothing elſe almoſt found between them but ſome very fine Matter which eaſily penetrates them; and becauſe they are protruded by the external Air, both the one and the other yield to the Exceſs of Force, approach one another, and are united, by a real Impulſion to which moreover they give the Name of Attraction, and they remain attached together in one common Vortex, which one may ſee deſcribed upon ſome Filings of Iron or Steel.

Eud. Let us ſeparate the Loadſtones, and preſent the two Poles of the ſame Name to one another, the two Meridionals, or the two Septentrionals. The Loadſtones ſeem to fly from one another. Would you not ſay that a ſecret Antipathy had ſuddenly ſucceeded to the ſtrongeſt Sympathy?

Ariſt. The Matter which impetuouſly flows from one Pole to the other of the ſame Name, not finding therein any Acceſs, becauſe it is not the Pole prepared for receiving it, or which received it in the Mine, thruſts it back with all its Force out of its Vortex, and does it the more effectually becauſe it moves with greater Velocity, until it find nothing more to ſtraiten its Sphere of Activity. The Loadſtones being protruded after this Manner towards oppoſite Parts, where they find contrary Forces leſs united, and Spaces more free, yield rather to the Exceſs of a foreign Force, than to the Motion of a ſecret Antipathy.

Eud. Let us only uſe one Loadſtone. I preſent to it a Plate of Copper; it does not attract it in the leaſt.

Ariſt. The Matter that iſſues out of the Loadſtone, with a Configuration proportioned to the Pores of the Loadſtone itſelf, not finding in thoſe of the Copper the ſame Diſpoſition for receiving it, does not run into them, neither is it united in a ſufficient Quantity, not to leave much Air between the Loadſtone and the Copper. Hence, the Air which remains, and the Matter which does not paſs through, repel the Copper. The Fluid, which paſſes through, and returns being reflected by the external Air, drives back the Plate, ſeconded by the Spring and Preſſure of the Air: The Plate being impelled towards two oppoſite Parts by equal Forces, obeys them equally, and remains at Reſt.

Eud. The Loadſtone attracts neither Lead nor Wood, by the ſame Reaſon. But if I bring a Plate of Iron near it, the Iron comes and applies itſelf to it.

Ariſt. The magnetic Matter meets with the ſame Configuration of Pores almoſt in the Iron as in the Loadſtone, which is found in Mines of Iron. It finds free Acceſs, runs into them, and is united in a ſufficient Quantity to drive out almoſt all the Air from between the Iron and the Loadſtone. The Air being driven out, returns backward upon the Loadſtone and the Iron. The Iron being violently propelled toward the Loadſtone, without finding any Obſtacle between the Loadſtone and it, becauſe it gives a free Paſſage to the magnetic Matter, follows the ſtrongeſt Impreſſion, flies toward the Loadſtone, and lays hold on it, as one Loadſtone lays hold on another.

Eud. On the ſame Principle one might ſee the ſame Diverſion in Steel. But let us put a Loadſtone upon Water in a little Boat of Paſteboard, and embark with it theſe little Figures; they are Toys and Play Things. Do not you obſerve the Loadſtone itſelf, followed with the Toys, come ſwimming in Queſt of the fixed Steel, which is preſented to it.

Ariſt. Since the Air driven from between the Loadſtone and the Steel, retires equally behind both, it thruſts equally the Steel toward the Loadſtone, and the Loadſtone toward the Steel. They both obſerve the Laws of Nature exactly; the Loadſtone which is free comes attended with the Toys in Queſt of the Steel, which is not ſo.

Eud. To this Plate of Steel attached to the Loadſtone, I affix a Weight of 28 Pounds. The Weight cannot looſe it from the Loadſtone. This Loadſtone equals that which *M. Huygens* made Uſe of [z], and is not inferior to that which was offered to Sale for 5000 Livres in 1702, and which weighing only ele-

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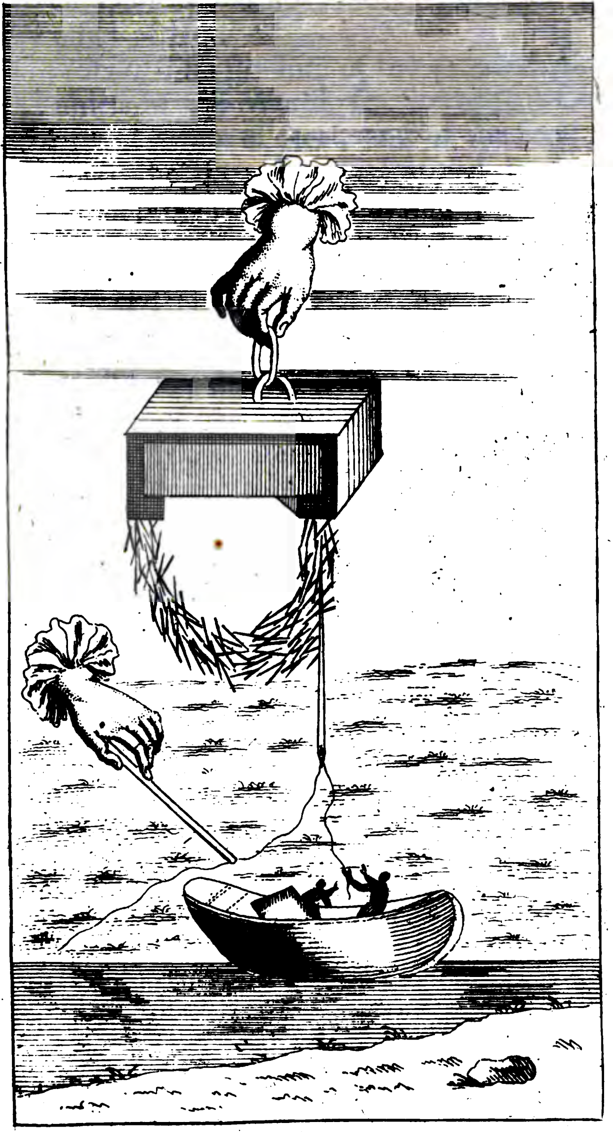
[z] Hiſt. de l'Acad. 1679. p. 184.



ven Ounces did notwithſtanding bear up 28 Pound of Iron *.

Ariſt. The Preſſure of the external Air, the Fulneſs of the World, the immediate Contact of the *Lamina* of Steel, and of the Steel with which the Loadſtone is armed in its two Poles, produce this ſurprizing Effect. The Preſſure, which proceeds from the Gravity of the Air, has a good Share in it. The Fulneſs of the World † is the Cauſe why the *Lamina* of Steel cannot be looſed perpendicularly, without ſome Matter ſucceeding in the Place of the ſolid Parts of the two Steels, which touch one another immediately; and it is very difficult for any Matter to flow there, becauſe a whole Plane muſt be ſeparated from another almoſt at the ſame Time, and the external Matter cannot, without extraordinary Efforts, ſlide along with Celerity enough not to leave any *Vacuum*.

Eud. The Armour, which conſiſts of Plates of Steel applied to the Pole of a Loadſtone, augments its Force very much. Certain Loadſtones being armed, are thereby made two Hundred Times ſtronger [a].

Ariſt. The inviſible Matter, which produces the Wonders of the Loadſtone, paſſes from the Loadſtone into the Armour of the Steel, as from a larger Bed into a ſtraiter one; it alſo paſſes therein with more Freedom, becauſe the

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* Hiſt. de l'Acad. 1702. p. 18. [a] Hiſt. de l'Acad. 1723. p. 102.

† Vide Notes CONVERSAT. V. and IX.

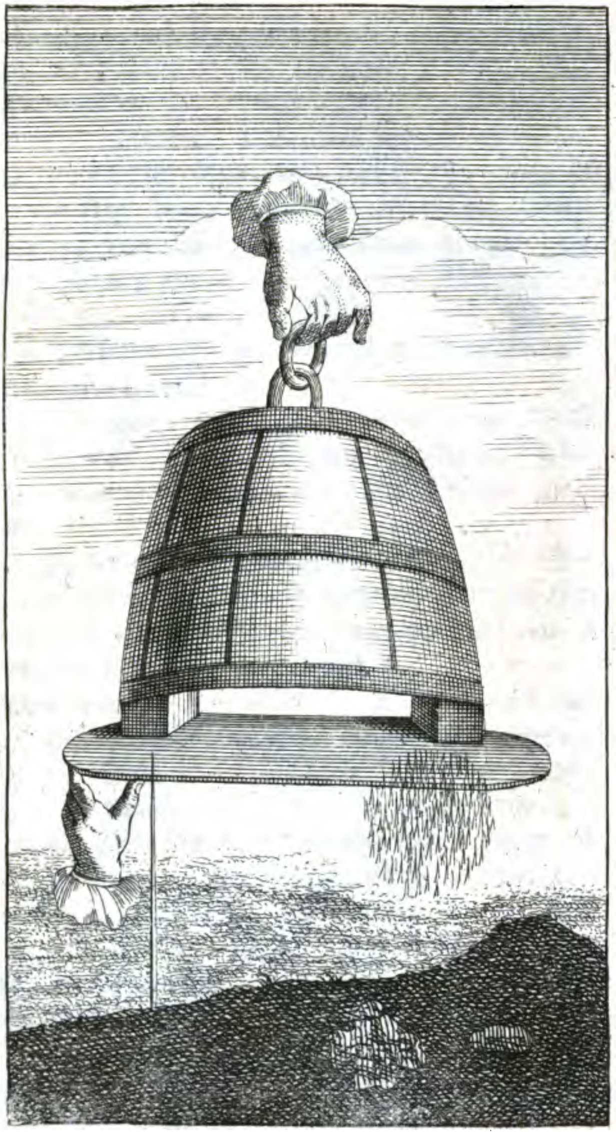
Steel

Steel is of a Matter more ſtiff than the *Magnet*, which is a Stone. Hence the magnetic Matter accelerates its Motion, and its Exceſs of Motion is an Exceſs of Force. Moreover, the Steel being ſmoother than Stone, there remains leſs Air between the Steel and the Bodies which are immediately attached to it, than betwixt the Stone and thoſe Bodies.

Eud. After this, need we be aſtoniſhed if the Loadſtone, to which I preſent Filings of Steel, becomes ſuddenly, as it were, briſtled? What ſurprizes me is, that putting a *Lamina* of Copper between the Filings and Loadſtone, the Filings are attached to the *Lamina* of Copper, without the *Lamina* being attached to the Loadſtone. I ſlide the Loadſtone over the upper Surface of the *Lamina*. You may ſee perpendicular Threads of Filings ſliding along at the ſame Time upon the inferior Surface. What magical Charm holds them attached by one of their Extremities, and makes them go and return rapidly, as at the Pleaſure of the Loadſtone?

Ariſt. The *Lamina* of Copper is not attached to the Loadſtone, becauſe the magnetic Matter not paſſing eaſily enough through the Pores of the Copper, as we have ſaid already, there remains much of this Matter and of Air between the Copper and Loadſtone. But that which paſſes, finding an eaſie Acceſs into the Filings, runs abundantly into them, and drives out almoſt all the Air which is found between

Vol. 1. p. 210.



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the *Lamina* and the Filings; no more *Equilibrium* of Forces at the oppoſite Ends of the ſmall Parts of the Filings; the Air driven out becomes victorious, protrudes toward the *Lamina*, and holds them attached to it. Such is the inviſible Bond. By the ſame Principle, whenever you ſlide the Loadſtone toward one Part, the Air carries thither the Threads of the Filings. This, I think, is the Spring which preſents to our Eyes the magical Diverſions of the Loadſtone.

Eud. I move the Loadſtone a little from the ſuperior Plane of the *Lamina*: The Enchantment ceaſes, and the Filings fall down.

Ariſt. When it is no more within the Vortex, at leaſt not in a powerful Part of the Vortex of the Loadſtone, the external Air is no longer ſufficient to ſupport it.

Eud. Let us lay aſide the *Lamina* of Copper, and preſent to the Loadſtone a ſewing Needle; there it is ſuſpended by the Point: What has made it of a ſudden, ſo ſenſible?

Ariſt. That which carries the Filings of Iron, Steel, and Loadſtone itſelf toward the Loadſtone, and holds them attached to it, ſuſpends the Needle upon the Loadſtone, and keeps it ſuſpended. The Air thruſts it toward the Loadſtone, by repelling the magnetic Matter towards it. There is nothing to hinder its being attached to the Loadſtone, becauſe there is no more Air, or much leſs Air between it and the Loadſtone; the *Equilibrium* being taken away, it only follows the Impreſſion of the greater Force in its being attached by the Point.

Eud. Let us turn the Loadſtone round the Needle of a Compaſs, placed horizontally upon an Axis, after ſuch a Manner that it may turn round. The Needle goes round with the ſame Velocity. Would you not ſay that it was afraid of loſing the Pole which attracted it?

Ariſt. One of its Extremities being continually drove by the expelled Air, which however returns upon it, while it is not equally repelled by the fine Matter which is alone, or almoſt alone, between it and the Loadſtone, it muſt yield, and endeavour to wait on the Loadſtone which flies away, by turning round upon its Axis.

Eud. If I make the Stone go round a contrary Way with the ſame Rapidity, the Needle returns and follows the Stone with the ſame Velocity.

Ariſt. The Needle, in returning, only follows the ſame Principle.

Eud Let us put the Loadſtone and Needle into Water. The Needle goes in Queſt of the Loadſtone, notwithſtanding the Obſtacle of the Water which it muſt cut every Moment, in order to come at it: The Reaſon is, becauſe there is certainly Air in the Water, as we ſhall ſee, and conſequently a ſubtile Matter which

expels

expels it, and diſturbs the *Equilibrium* of oppoſite Forces, as without. The Air being expelled, but victorious in its Return, forces the Needle to retire toward the Loadſtone. The Needle would diſcover the ſame Forwardneſs to unite itſelf to the Loadſtone, and the ſame Reſtleſneſs in an Air-Pump, out of which one had pumped the Air, becauſe ſome Air ſtill remains, at leaſt a ſubtile Air.

Shall we, *Ariſtus*, make a Whirligig go round, whoſe Axis is of Steel? It is permitted to Philoſophers themſelves to toy, when the Buſineſs is only to unravel Truth. I preſent the Plane of the Head of the Armour to the ſuperior Extremity of the Axis. The Axis lays hold of the Plane, and is attached to it; and the Whirligig being ſupported merely by an inviſible Force, turns round but the ſwifter.

Ariſt. The Whirligig riſes like the Needle; the ſame Force produces two ſimilar Effects. But why does the Whirligig continue to turn round? Becauſe its perpendicular Direction is not oppoſed to the circular Motion, which it had before the Loadſtone bore it up. If it turns round with a greater Celerity, that is becauſe the Plane, which it touches, is more poliſhed.

Eud. Let us forbear toying, and take again two Loadſtones, the one ſtronger and the other weaker. I apply them both to a Piece of Iron by the two oppoſite Sides. With the weaker I ſnatch away the Iron from the ſtronger, which however does not always happen, But how can the weaker prevail over the ſtronger?

Ariſt. When the Fact happens, it is probably becauſe the ſtronger does not touch the Iron ſo exactly as the weaker, that conſequently there remains ſome Air between the ſtronger and the Iron, and the Effort of the internal Air, for ſeparating the Iron from the Loadſtone, exceeds the Exceſs of Weakneſs which is found in the weaker. The weaker ſeconded by the Air, which remains between the ſtronger and the Iron, prevails ſo much the more effectually, becauſe being within the Vortex of the ſtronger, it participates of the Force of the ſtronger, whoſe Vortex unites it firmly to the Iron. In ſhort, withdraw the weaker from this Vortex, and it will quickly let the Iron fall.

Eud. One Experiment more, and we will finiſh this Converſation.

Fig. 18. I ſuſpend a lighted Wax-Candle *(a)*, under an oblique Plane *(b)* thin, moveable, and which can turn round upon a poliſhed Axis *(c)*. I hang a Loadſtone upon the other Side *(d)*, over the Water *(e f)*. The Plane, Flame, and Loadſtone turn round, and the Loadſtone is agitated. Small enamelled Figures being *(g)* bored through with an Iron-Wire, follows it ſwimming.

Ariſt.

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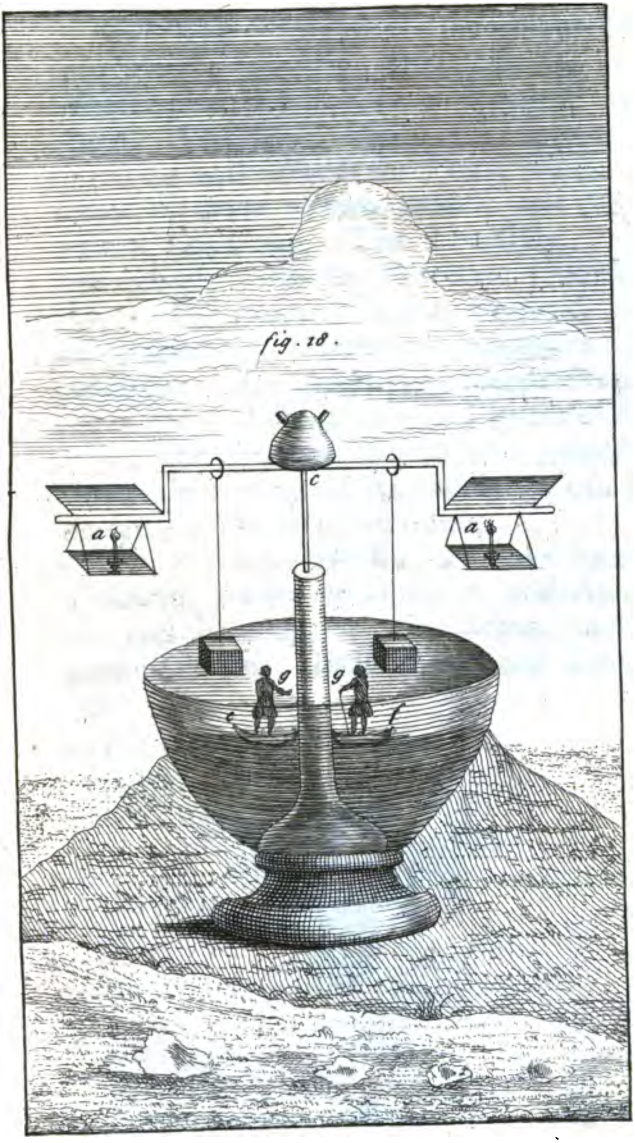

fig. 18.

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Ariſt. The Flame makes the oblique Plane turn round, after the ſame Manner as the Wind makes the Sails of a Windmill to go round. The Plane, which turns round, carries along with it both the Flame which continues to make it turn round, and the ſuſpended Loadſtone. The Loadſtone, which goes round, loſes its Direction toward the Poles. The magnetic Matter ſtrikes it, in order to reſtore it. Hence the Inquietude of the Loadſtone. The Air being expelled from between the Loadſtone and the Figures of Steel, drives the Figures toward the Loadſtone. Hence their apparent Senſibility, or this Forwardneſs to follow it ſwimming.

Eud. Hitherto, *Ariſtus*, we have ſeen the wonderful Effects of Direction and Attraction; this Evening we will obſerve thoſe of Communication, Inclination, and Declination.

CONVERSATION XVI.

Upon the Communication, Inclination, and Declination of the Loadſtone.

Eud. I Rub a Knife, according to its Length, from the Handle to the Point, by conducting it from one Pole of the Loadſtone to the other. The Knife, which I have rubbed, lifts up Iron Nails, Keys and Needles: The magnetic Virtue has paſſed into the Knife, without ceaſing to be in the Loadſtone. Let us preſent to the Loadſtone a Needle placed upon the Axis of the Needle of a Compaſs. The Needle has already its Poles turned toward the Poles of the World. I preſent a Pole of the Loadſtone to the Point of a ſewing Needle; it is there ſuſpended perpendicularly by the Point. The other Extremity of this Needle draws to it a ſecond by the Point, the ſecond a third, the third a fourth, the fourth a fifth, the fifth a ſixth, &c.

Ariſt. The magnetic Matter, which had made itſelf in the Iron, while it was with the Loadſtone in the Mine, Pores much like thoſe of the Loadſtone, improves them by paſſing impetuouſly from the Loadſtone into the Iron or Steel, gives theſe Pores the Configuration which it retains in coming out of the Stone, conſequently diſpoſes them to receive it preciſely on one Side, and to let it paſs out preciſely by another, gives its Direction to the magnetic Matter wherewith the Iron is penetrated, and by that Means makes two Poles: This is Communication, and thus the Iron and Steel, Needle and Knife become at once new Loadſtones.

Eud. The Needle, Knife, and Rods of Iron or Steel aſſume the magnetic Virtue according to their Length; the Ends become Poles. Does the Loadſtone touch one Extremity? The other is endued with a magnetic Virtue.

Ariſt. The Reaſon is, becauſe the magnetic Matter, finding therein more ſolid Pores, Pipes, and Paſſages more proportioned to its Configuration, and leſs interrupted, wherein it muſt communicate leſs Motion than in the Air, whoſe Parts are more ramoſe, it flows in them more eaſily than in the Air itſelf. Hence the Rods of Iron or Steel being put into a Situation parallel to the Meridian, the Fire-tongs themſelves become magnetic according to their Length, in receiving the Fluid which iſſues out of the Boſom of the Earth.

Eud. A Knife, that ſlides Croſs-ways upon the Pole that endued it with a magnetic Virtue, loſes ſometimes its Virtue all at once.

Ariſt. The Matter, which finds the Parts of the Iron and Steel more flexible than thoſe of the Loadſtone, enters impetuouſly into the Iron and Steel through the Pole prepared for letting it paſs out; raiſes up again the Particles Croſs-ways, the ſmall Hairs which at firſt it had made to incline to one Side; changes the firſt Configuration of the Pores, and by that Means ſhuts up the Paſſage againſt itſelf.

Eud. By the ſame Principle, the Needle of a Compaſs loſes its Virtue, when it is too long retained in a Situation parallel to the Meridian, but contrary to the Courſe of the magnetic Matter. You need but hold the North-Pole of the Load-ſtone applied to the North-Pole of a magnetic Needle, and it becomes Magnetic the contrary Way.

Ariſt. The Reaſon is, becauſe the magnetic Matter finds the Particles of the Needle ſufficiently pliable and flexible for receiving at once a contrary Arrangement and Configuration.

Eud. Sometimes in this Change the magnetic Virtue is only augmented.

Ariſt. That is, becauſe the Particles of Steel being turned an oppoſite Way, thereby become only more flexible, and fitter for yielding to the Current of the Fluids.

Eud. Would you imagine that Thunder could give a new Direction to the magnetic Needle, as well as the Loadſtone? But one Day all the Needles of an *Engliſh* Veſſel, upon which the Thunder fell, immediately took a new Direction, and ſo conſtant, that they could not change it. The Pilot of the Veſſel reſumed the ſame Courſe he had made, without knowing it, till the Pilot of another Veſſel made him obſerve in the Direction of his Needles the new Phenomenon of the Thunder[b].

Ariſt. Probably the magnetic Matter being forced by the Violence of the Thunder to flow back impetuouſly through the ſame ſmall Paſſages of the Needles, made the ſmall Parts of thoſe Ducts to take oppoſite Configurations and Directions.

This Phenomenon, *Eudoxus*, brings into my Mind the Obligation which the whole World is under to the *Portugueſe*, who purpoſing to diſcover the *Indies*, found out, or improved at leaſt, a Thing more to be eſteemed than the Riches themſelves of the *Indies*, that is the Compaſs[c]. This Invention is ſo glorious to thoſe who were the Authors of it, that in ſome Meaſure we owe to them the greateſt Part of the Diſcoveries which have been made in different Parts of the World.

Eud. They pretend that the *Chineſe* had the Uſe of the Compaſs, long Time before*. However that be; Will you believe it, *Ariſtus?* According to the Experiments of *M. de Reamur*[d], Iron gives a magnetic Virtue to Iron, without touching the Loadſtone, and alſo to itſelf when it is broken. Being placed vertically it becomes magnetic, not only after a conſiderable Time, as Shovels and Pincers; or after many Years, as the famous Croſſes of the Bells of *Aix* and *Chartres*; but in a Moment. Almoſt all the Tools, which cut or pierce Iron in a cold State, as Sciſſars, Bodkins, and Gravers, are immediately endued with magnetic Virtue; ſince whenever they have cut or bored Iron, they begin to be charged with Filings of Iron[e]: When you break Iron by having bent and twiſted it different Times in the ſame Part, you will find it become magnetic in the breaking; the two Ends where it is broken, attract Filings of Iron or Steel[f].

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[b] Journ. des Sçav. 1 *Mar.* 1677. p. 61.

[c] Maffée Hiſt. des *Indes.* Journ, des Sçav. 1666. p. 118.

* Le Pere le Comte, derniere Lett. du Tom. I.

[d] Mem. de l'Acad. 1723. p. 81.

Laſtly, a Bar of Iron placed vertically acquires two Poles in an Inſtant. The lower End attracts the Point of the Needle which ordinarily faces the South; and towards the upper End there is a Pole which attracts the North Point. The two Poles change, whenever the Bar happens to be in an oppoſite Situation.

Ariſt. It is very probable that the Iron is penetrated with a magnetic Matter, impriſoned, as it were, and that there are in the Iron ſeveral ſmall Vortexes of this Matter, weak and irregular, which give little Strength to the Iron, becauſe they do not concur to the ſame Effect. It is in Mines of Iron that the Loadſtone acquires its Force; and Bodies which have the Virtue of Attraction, attract more Filings when they are placed upon ſome other Iron. If you remove from an Anvil magnetick Iron, which has charged itſelf thereon with Filings, immediately it loſes its Force, and lets fall what it bore[g]. Probably becauſe the Iron has its Atmoſphere, which augments its Vortex. The greater the Vortex is, the greater is the attractive Virtue. A weak Loadſtone increaſes in Force in the Vortex of a ſtronger one[h].

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[e] Mem. de l'Acad. 1723. p. 82, 83. [f] p. 92, 93.

This being granted; 1. When a Tool of Iron or Steel cuts or bores Iron, the Matter expelled from the diſordered or contracted Pores of the Iron, is darted out into the Tool, whoſe Parts being harder, and more ſeparated by the Effort of the Operation, preſent more free Pores or Paſſages to the magnetic Matter; and it gives the Matter which it encounters therein its Direction from one End to the other. Hence the Tool has its two Poles; and it becomes Magnetic.

2. When one breaks Iron after having bent it, the internal magnetic Matter being violently agitated by the Torture, finds Paſſages in the two Ends of the Fracture, is united in them, runs off, and being repelled by the Air, returns alternately with the Filings of Iron.

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[g] Mem. de l'Acad. 1723. p. 29.

[h] P. 90.

Thus Iron becomes magnetic without the Help of the Loadſtone.

3. Finally, when one places a Bar or Rod of Iron vertically, the magnetic Matter probably runs along through the Iron while it iſſues out of the Earth with Impetuoſity, and by the Violence of its Action it makes two Poles, the one in the lower End, and the other in or towards the upper End.

Eud. The attractive Virtue of a Tool, which cuts or bores Iron, is augmented under the repeated Blows of the Hammer.

Ariſt. Under each Blow ſome new Matter being forced to penetrate the Tool, enlarges the open Paſſages, and opens itſelf new ones; and a more abundant Circulation increaſes the attracting Power.

Eud. After a certain Number of Operations and Efforts, it is augmented no more.

Ariſt. The magnetic Matter finding at laſt a ſufficient Number of Paſſages in the Steel, it more eaſily follows the firſt, than it opens new ones for itſelf; and as the Vortex does not increaſe any more, the Force is not augmented.

Eud. Sometimes the Blows of the Hammer make Iron loſe the Virtue of Attraction forthwith.

Ariſt, That is, becauſe they immediately ſtraiten or ſhut up the Paſſages of the magnetic Matter.

Eud. Iron, which retains its Force, bears more Weight near a great Maſs of Iron, than when it is near a Bar.

Ariſt. The great Maſs, having a greater Atmoſphere, yields more magnetic Matter, and conſequently more Force.

Eud. An Iron-Wire, about the Thickneſs of one's Finger, and rendered magnetic by breaking, acquires ſo much the more Force, the greater Number of Places it is bent and twiſted in[i].

Ariſt. More Paſſages are opened for the magnetic Matter.

Eud. Too many Inflections make the Iron-Wire loſe its Force.

Ariſt. Too many Inflections expel the magnetic Matter, or at leaſt ſtop its Paſſages.

Eud. An Iron-Wire ſtruck with the Blows of an Hammer, does not become Magnetic.

Ariſt. The Wire being narrow and almoſt equally compreſſed in thoſe Parts where it has received the Blows, has no longer any convenient Place left in it for the magnetic Matter, wherein it may be lodged, or through which it may paſs.

Eud. But a large Bar becomes magnetic under the Hammer, if one ſtrike it with the ſmalleſt End of the Hammer only in the Middle, or near one of the Edges of the Bar.

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[i] Mem. de l'Acad. 1723. p. 94.

Ariſt. In this Caſe the expelled Matter ſtill finds a Lodging in the Iron, and a Place which affords it a free Paſſage.

Eud. But why do thoſe Tools become magnetic which cut Iron while cold, and not thoſe which cut it while hot?

Ariſt. As the Fire dilates the Pores of red-hot Iron, the Point or Edge of the Tool does not ſtraiten the magnetic Matter, nor Force it to paſs into the Tool.

Eud. But finally the Tool, which cuts or bores red-hot Iron, loſes its attractive Virtue.

Ariſt. That is probably becauſe in the Action the magnetic Matter paſſes with more Facility into the hot Iron, and quits the Steel; or becauſe the Heat diſorders the Parts, and ſtops up many Paſſages of the Steel.

Eud. From theſe ſurprizing Effects of Communication let us paſs, *Ariſtus*, to Inclination. Inclination is a Situation wherein one of the Poles of the Loadſtone, or elſe of a Body touched with the Loadſtone, inclines more than the other toward the Earth. This Property will be better manifeſted in a magnetic Needle, than in the Loadſtone itſelf. Therefore let us place horizontally, upon two ſmall Props, a Needle bored through the Middle, at right Angles, by a ſmall Braſs Wire, which ſerves to ſupport it. The Needle is moveable, and in *Æquilibrium*; I make the Loadſtone paſs over it, from one End to the other, from North to South; the End which faces the

North, or the meridional Pole of the Needle, far from pointing to the polar Star, falls and deſcends. The magnetic Needle, which guides our Veſſels, is differently inclined in different Countries.

Ariſt. The magnetic Matter enters or comes out more eaſily, more ſwiftly, and more abundantly through the Poles of the Loadſtone, than through its Equator, ſince there is a greater Force in its Poles. I ſay the ſame likewiſe of the Poles of the Earth; in ſhort, the magnetic Matter circulates from one Pole of the Earth to the other. This being granted, when the Loadſtone has paſſed over an horizontal Needle in Northern Countries, the Matter which iſſues out of the North Pole of the Earth, flows abundantly into the South Pole of the Needle. Now if the Matter paſs more eaſily from the South Pole of the Needle into the North Pole of the Earth, or in greater Abundance from the North Pole of the Earth into the South Pole of the Needle, its South Pole ought to incline to the Horizon. The Matter which paſſes more eaſily from this Pole into the Earth, takes a Direction toward the Earth in its iſſuing out, and gives it to this Pole by ſtriking it, and driving out more Air from between the Earth and it: The Matter which paſſes more abundantly from the Earth into the ſame Pole in circulating, produces the ſame Effect in its Entrance, it being reflected by the ſuperior Air.

Eud. In a Word, if I place the North Pole of this Loadſtone under the South Pole of the Needle, it is inclined to the Horizon. If I place the South Pole of the Loadſtone under the North Pole of the Needle, it alſo is inclined in its Turn. Hence when our Veſſels come from North to South, or from South to North, the Needle of the Compaſs is uſually parallel enough to the Horizon under the Equator. But in Proportion as one advances from the Equator toward the North, the South Pole of the Needle is inclined; and in Proportion as one advances from the Equator toward the other Pole of the Earth, the North Pole of the Needle is inclined: A Situation conformable to that of the magnetic Matter, which deſcends or aſcends obliquely toward the Poles, and is parallel to the Horizon under the Equator, as the Matter which makes the Vortex of the Loadſtone, and which deſcribes its Way and Direction upon the Filings of Steel. But finally what is the Declination of the Loadſtone?

Ariſt. It is a Motion which makes its Poles diverge from North and South toward Eaſt or Weſt.

Eud. In the Beginning of the laſt Age, the Declenſion at *Paris* was from ſix to eight Degrees from North to Eaſt; in 1640 about three Degrees[k]; In 1650 betwixt five and ſix Degrees;

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[k] Journ des Sçav. 1681. p. 19.

grees; in 1666 *Paris* was without any Declenſion[l]. In 1681, the Declenſion at *Paris* was two Degrees and 50 Minutes from North to Weſt[m]. In 1684, four Degrees 10′. In 1687 it was ſcarcely one Degree[n]. The 11th of *October* 1717, it was 12 Degrees 45 Minutes. The 16th of *July* 1728, it was 13 Degrees 50 Minutes. From the 16th of *October* 1720, to the 3d of *January* 1725, 13 Degrees[o]. Theſe Variations are obſerved toward the Weſt and and in the *Eaſt-Indies*, as here[p]. Some Places are without Declination. The Variations are different in different Places. Whence can this aſtoniſhing Phenomenon proceed?

Ariſt. It may proceed from the Changes which happen in the Earth. New Mines of Iron, old Mines exhauſted, Mines differently ſituated, the Configuration of the Pores being changed toward the Surface of the Earth, by the Action of ſubterraneous Waters or Fires, all this may vary the Courſes of the magnetic Matter; and the Variety of thoſe Courſes, their different Direction, ought naturally to cauſe a Difference in the Direction of the magnetic Needle. Should there come more magnetic Matter, or with more Force from one Side, the Needle would be carried that Way. Preſent to it two Loadſtones, one of which is ſtronger; and you may ſee it decline toward the ſtronger.

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[l] Hiſt. de l'Acad. 1712. p. 20. Journ. des Sçav. 1681, p. 19.
[m] Journ. des Sçav. 1681. p. 19.
[n] Journ. des Sçav. 1687. p. 93.
[o] Mem. de l'Acad. 1724. p. 8. 1725. p. 5.
[p] Hiſt. de l'Acad. 1685. p. 248.

A *Spaniſh* Author, who was returning from *Peru* into *Spain*, having gone down into an excellent Mine of Loadſtone, compoſed of two principal Veins which croſſed one another, and one of which was extended from South to North; and the other from Eaſt to Weſt, he diſcovered in this Mine a Line, which went from South to North, and was two Fingers broad, where the Needles fixed on the North Point. After that he placed them to the Weſtward of the Line, and they declined from North to Eaſt. At laſt he placed them to the Eaſtward of the ſame Line, and he ſaw them decline from North to Weſt.

The ſame Author tells us of different Mines, which cauſe divers Variations. According to his Obſervations the greateſt Part of thoſe Mines is upon Coaſts or in Iſlands; and conſequently within Reach of acting upon the Needles of Veſſels, which are not too far diſtant from them. If the Veſſels are too far diſtant from them, there is no Cauſe of Variation, and the Needles fix toward the North[q].

According to the Obſervations of Father *Noel*[r], who travelled four Times to *China*.

1. At the *Cape of Good-Hope* the Declination of the Loadſtone in 1667, was ſeven De-

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[q] Dom. Franciſco, Journ. des Sçav. 1704. p. 364, 5, 6.

[r] Journ. de Trevoux 1712. p. 700.

grees 15 Minutes toward the Weſt; in 1702, 12 Degrees 50 Minutes. In 1706, 13 Degrees 40 Minutes. In 1708, 14 Degrees.

2. The Variation of the Loadſtone is different in different Places, and paſſes ſucceſſively from Weſt to Eaſt, and from Eaſt to Weſt. The Declenſion toward the Weſt decreaſes continually from *Liſbon* to the Height of the Iſland of *Fer*; whence the Declenſion paſſes to the Eaſt, and increaſes to about 360 Leagues from the *Cape of Good-Hope.* There it returns to the Weſt as far as the Height of *Madagaſcar*; after that to the Eaſt, as far as the narrow Paſs of the Sound; and at laſt to the Weſt, paſſing from this Straight to *Ceilan* and *Goa.* Under the Meridian of the moſt ſoutherly Cape of *Madagaſcar*, making a Tour toward the South Pole, the Compaſs declines more and more toward the Weſt, 20 Degrees at the Latitude of 30 Degrees 40 Minutes, and 36 Degrees at the Latitude of 36 Degrees.

Theſe Variations do not agree with the Meridians; and how can they be adjuſted with the great Circle of magnetic Matter, in which the Mines of Iron and Loadſtone, being ſpread abroad in ſeveral Parts, cauſe no Irregularities?

Eud. The Meſſieurs *de la Hire* have indeed repreſented the Globe of the Earth by a Loadſtone formed round, of 100 Pounds, and almoſt a Foot and an half in Diameter, having an Equator and Meridians deſcribed upon its

Surface. The Needle of a Compaſs, placed ſucceſſively upon thoſe different Meridians, had ſometimes a Declenſion toward the Weſt, ſometimes toward the Eaſt, and ſometimes it had none at all [s].

These Variations proceed probably from divers Mixtures irregularly diffuſed in this Stone. Now, is not the Earth and Loadſtone ſtill more fixed?

In the mean Time Dr. *Halley*'s Diſcovery concerning the Declination of the Loadſtone deſerves our Attention. This learned *Engliſhman* found in a Voyage, which he made to the South Countries in 1700, in order to ſearch out the Truth there, four different Places in which the magnetic Needle did not decline.

1, At 18½ Degrees of Weſt Longitude, reckoning the Longitudes of the Meridian from *London*, at two Degrees of North Latitude.

2. At four Degrees of Weſt Longitude; at 37½ of South Latitude.

3. At 10 Degrees of Weſt Longitude; at 16¾ of South Latitude.

4. At 64 Degrees of Weſt Longitude; at 31½ of North Latitude.

When he had theſe four Points, he conceived an Idea of a crooked Line, pretty irregular, deſcribing round the terreſtrial Globe, having on one of its Sides the Places where the

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[s] Hiſt. de l'Acad. 1705. p. 8.

Declenſion would be eaſterly, and upon the other thoſe where the Declenſion would be weſterly. He had the Pleaſure of ſeeing that all his Obſervations, during his Voyage, agreed with ſo lucky a Thought; and he deſcribed this curve Line upon a Map.

M. Marchais in a Voyage to *Guinea* and *America*, *M. Houſſaye* in an *Eaſt-India* Voyage, and *M. de May* in a *China* Voyage, found the Declenſions of the Needle little differing from Doctor *Halley*'s Chart. The ſuppoſed Line is moveable, and appears to advance always toward the Weſt in Regard of us. A *French* Veſſel which went to *China* in 1710, through the South Sea, found another Line without any Declenſion, which croſſes the South Sea from North to South, much like a Meridian. Formerly there was no Declenſion of Needles obſerved at the *Cape*.

Ariſt. Doctor *Halley*'s Notion appears to me very remarkable; but I think there are ſtill wanting ſeveral Experiments for illuſtrating and confirming it.

Eud. There is ſo much the more Need of them, becauſe in the ſame Place the Declination is not equally varied in equal Spaces of Time. If one perceive any Species of Progreſſion, it is ſtill very imperfect; and the Cauſes of the Declenſion which you have mentioned, will ſtill probably prevail for ſome Time.

We ſhall ſay nothing of the Cauſes which deſtroy the magnetic Virtue. It is evident that whatever may ſtop the Pores of the Loadſtone, as Ruſt and Air itſelf, or may change their Configuration, as Fire, may deſtroy it. But before we conclude our Converſation, you muſt tell me why the greateſt Part of precious Stones, Glaſs, Gum, *Spaniſh* Wax, Amber and Jet being rubbed, attract Chaff and other light Things, in ſome Sort imitating the Attraction of the Loadſtone.

Ariſt. A violent Agitation, a ſort of Heat cauſed by rubbing in the ſubtile or fine Matter, which penetrates the precious Stones, the Glaſs, *&c.* makes a kind of Vortex iſſue out of them, as out of the Loadſtone, of Matter which paſſes more eaſily through Motes than Air, and whoſe Celerity at firſt compreſſes and expels the Air; but in a ſhort Time the compreſſed and expelled Air is dilated and becomes victorious, drives the Chaff and Motes it meets with towards the precious Stones, *&c.* and applies them to the ſame ſo much the more effectually, as the Matter which darted from thoſe Bodies after rubbing, has communicated and loſt the Force which it had acquired in the rubbing itſelf; and this is the Attraction of precious Stones, Glaſs, Gum, *Spaniſh* Wax, Amber, Jet, *&c.*

Eud. Here are many philoſophical Myſteries happily enough explained, *Ariſtus*; and theſe Illuſtrations will give ſome Light into what we ſhall ſay hereafter upon Gravity, and other Matters.

Ariſt. Gravity is a thorny Subject, but curious; and I know an excellent Source, whence I could draw ſome Light, even before I hear you. I ſhall return to your Cloſet, as ſoon as poſſible; ſcarcely am I gone out of it, but the Reliſh of Truth calls me back again.

CONVERSATION XVII.

Upon Gravity.

Eud. I Am miſtaken, *Ariſtus*, or you are ſatisfied with your Knowledge concerning Gravity. The Pleaſure which Philoſophers find in Truth, appears in your Countenance. It is not a chimerical Pleaſure, but philoſophical, modeſt and pure, which is felt and appears outwardly without any Alteration, either in the Body or Mind. I am impatient to ſhare this Pleaſure with you. Therefore tell me in the firſt Place what is Gravity.

Ariſt. The Gravity * of Bodies is the Effort which they make to tend toward a common

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* *The Gravity or Weight of Bodies is an accelerating Force; and this Gravity or Weight at the Surface, or at equal Diſtances from the Center of the Earth, is directly proportional to the Quantities of Matter contained in ſuch Bodies.* That Bodies preſs

Center; as Levity is their Effort to remove from it. For they call thoſe heavy Bodies, which, whenever at Liberty, move towards a common Center as of themſelves.

Eud.

preſs continually, or tend equally and uniformly to the Center of the Earth, and conſequently, that this Gravity or Weight is an equally accelerated Force, is evident to Senſe, as a moſt undoubted Matter of Fact; and it likewiſe farther appears from the moſt accurate Obſervations and Experiments.

Firſt, That the accelerating Velocities, acquired by Bodies in their perpendicular Deſcent, reckoning from the Beginning of their Motion, are ever as the Times in which they are acquired, and the Spaces deſcribed as the Squares of the Times.

Secondly, That abſtracting from the Reſiſtance of the Air, the Space deſcribed by the perpendicular Deſcent of a Body in one Second of Time, is equal to 16,1 *Engliſh* Feet, and for any longer or ſhorter Time, as the Squares of thoſe Times reſpectively.

Thirdly, That the Reſiſtance of the Air being taken off, or allow'd for, the accelerating Velocities of all Bodies near the Earth's Surface, are exactly equal; the lighteſt Bodies deſcending as ſwift as the heavieſt, and the leaſt as ſwift as the greateſt: The different Magnitudes, Denſities, and particular Figures, Textures and Conſtitutions of Bodies, making no manner of Difference as to their Velocities of Deſcent; which in all Bodies alike are ever equal, in equal Times, and proportional to the Squares of thoſe Times. Now ſince the *Momenta* or Quantities of Motion, in Bodies whoſe Velocities are equal, are as their Quantities of Matter, and ſince the accelerating Velocities of all Bodies deſcending by the ſole Force of their own Weight, are likewiſe equal, by what has been juſt now obſerved; 'tis evident that the abſolute *Momenta*, or Quantities of Motion in all ſuch Bodies, are likewiſe as their Quantities of Matter: But theſe *Momenta*, or abſolute Forces of deſcending Bodies, are nothing elſe but their abſolute Gravities, by which they preſs continually, or tend equally and without Intermiſſion to the Center of the Earth; and therefore this abſolute Force of Gravity, or Weight in Bodies, is exactly proportional to their Quantities of Matter.

Corol. From hence it follows, that there are Vacuities or empty Spaces in Bodies. For ſince in Conſequence of this Proporti-

on,

Eud. Let us ſpeak here only of the Gravity of terreſtrial Bodies. We ſhall make our ſelves the better underſtood; and what we ſhall ſay will be of Uſe for comprehending the Gravity of all other weighty Bodies.

Ariſt. The Gravity of terreſtrial Bodies is their Effort toward the Center of the Earth.

Eud. Do you only acknowledge one Sort of Gravity?

Ariſt. I diſtinguiſh two Sorts, the one abſolute, and the other relative. I call abſolute Gravity, the Gravity of a Body, conſidered preciſely as the Gravity of that Body, without comparing it with the Gravity of any other, more or leſs weighty. I call relative Gravity, the Gravity of a Body conſidered with Relation to another more or leſs weighty.

Eud. But whence proceeds Gravity, whether it be abſolute, or relative? Is the Cauſe external to the heavy Bodies? The Antients ſaid, not; the Moderns affirm it; what think you?

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on, the Weight of Bodies is proportional to their Quantities of Matter; and ſince upon the Suppoſition of an abſolute *Plenum*, the Denſities of all Bodies muſt be equal, or an equal Quantity of Matter every where contained in equal Spaces; 'tis evident, that upon this Hypotheſis, the Weight of Bodies muſt be ever proportional to their Bulk or Magnitude, and there could be no Difference of ſpecific Gravity in Bodies; which being moſt notoriouſly contrary to Fact, muſt evidently and demonſtratively overthrow that Hypotheſis of an abſolute *Plenum*, upon which it is founded. *Morgan's Phil Princ. of Med.* p. 8.

Ariſt. A Cauſe, which moves Bodies, is external to the Bodies; Bodies of themſelves being only, each in particular, a Portion of Extenſion * indifferent to Motion or Reſt, they have no Efficacy, no ſecret Quality, which ſhould make them prefer Motion to Reſt. Now the Cauſe of Gravity moves heavy Bodies; for whenever they are free, you ſee them paſs from Reſt to Motion, you ſee them fall; Therefore the Cauſe of Gravity is external to weighty Bodies.

Eud. This external Cauſe, which we do not ſee, and which notwithſtanding immediately drives Bodies toward the Center of the Earth, muſt it not ſtill be the ſubtile Matter; that Matter which appeared ſo new to you, and whoſe Idea ſeemed to quicken your Imagination in our firſt Converſations?

Ariſt. That which immediately impels ſenſible Bodies towards the Center of the Earth, is an inſenſible Body. It is a Body, ſince it impels, ſtrikes and touches heavy Bodies. This Body is inſenſible; the Senſes do not perceive it. This inſenſible Body is the Air, or ſubtile Matter: It is not the Air; we ſee Bodies deſcend being protruded by an imperceptible Force, ſo as no Body can ſuſpect that the Air protrudes them. Invert into Quickſilver a Glaſs-Tube of ſix and thirty Inches, likewiſe full of Quickſilver: You may ſee the Quickſilver deſcend at leaſt eight Inches; neither is there any Air above which can thruſt it downward; the Air does not penetrate a Glaſs-Tube. Therefore the ſubtile Matter is the external and immediate Cauſe of the Gravity of Bodies.

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* Rather of Subſtance or Matter, which is not Extenſion itſelf, but ſubſiſts in Extenſion, or extended Space.

Eud. I acknowledge it, and look upon this Reaſoning as a phyſical Demonſtration. But the inferior ſubtile Matter, which touches, thruſts, and immediately precipitates heavy Bodies, cannot give them a Direction toward the Center of the Earth, without having ſuch another. Whence hath it one? This is what has not been demonſtrated.

Ariſt. Probably it has it from the two Vortexes † of the ſuperior ſubtile Matter. In one of thoſe two Vortices the ſubtile Matter turns round about the Axis of the Earth, and in the ſecond, from one Pole toward the other.

Eud. Have not theſe two Vortices a great Appearance of being the Work of a lucky Imagination?

Ariſt. The firſt Vortex is not imaginary; I prove it. The Moon turns round the terreſtrial Axis, always ſurrounded with ſubtile or ætherial Matter. For the Light of the Sun being reflected by the Moon ſtrikes our Eyes. The Matter, in which the Moon ſwims, turns about with it; otherwiſe the Moon finding always ſome Reſiſtance in the Liquid, which it muſt cut through and divide, would communicate and loſe its Force every Moment, and at laſt would ceaſe to run over the Heaven, as it has done with equal Pace for the Space of ſix Thouſand Years paſt. Now the celeſtial Matter, which contains the Moon in its Boſom, cannot turn round with it about the Earth, unleſs the firſt Vortex be real.

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† See Notes CONVERSAT. XV. Vol. III.

The ſecond Vortex is no more imaginary than the firſt. A magnetic Needle, as well as the Loadſtone at Liberty, has two Extremities, two Poles, which ſeem always to ſearch out the Poles of the Earth with ſome Inquietude. The Needle has not this Direction of itſelf, being only a Portion of Matter very indifferent of itſelf to all imaginable Directions. It muſt conſequently receive it immediately from ſome agitated Matter, which has a conſtant Direction from one Pole of the Earth to the other, as you made me obſerve when you diſcourſed of the Loadſtone. This Matter being agitated from Pole to Pole, is either the Air or ſome finer Matter, ſome ſubtile Matter, ſince it is an imperceptible Body. It is not the Air; the Air has no conſtant Direction, but is indifferently carried toward a Thouſand Parts at the Pleaſure of the Winds: Therefore it is a finer Matter, a ſubtile Matter, which circulates from Pole to Pole. And here is the ſecond Vortex of ſubtile Matter as real as the firſt.

Eud. I muſt indeed at laſt acknowledge your two Vortices, which croſs one another in ſuch Sort, that the one ſeems to paſs wholly under the other, as to penetrate it much after the ſame Manner as Water penetrates a long Pile of Bullets which it croſſes. But after what Manner do thoſe Vortices give the ſubtile Matter, which immediately encompaſſes us, the Direction which it gives us toward the Center of the Earth?

Ariſt. 1. The Vortex, which turns round about the Axis of the Earth, gives the ſubtile Matter that is a little groſſer, a Direction perpendicular to the terreſtrial Axis; for according to the general Rule of Motion, when many unequal Bodies turn all round at the ſame Time about a common Center, thoſe which have the greateſt centrifugal Force, or which are fitteſt for Motion, prevail over the weaker, and precipitate them toward the Center of their Motion. 2. The Vortex which paſſes through the Poles, and carries along an infinitely fine Matter from Pole to Pole, gives this Matter a Direction almoſt parallel to the Axis of the Earth. The inferior and groſſer Matter, having one Direction perpendicular, and another parallel, in order to obſerve the third general Rule of Motion, takes a Middle Direction, deſcribes a Diagonal which directs it toward the Center of the Earth, and toward this common Center it thruſts all that it encounters in its Way; ſo that groſs Bodies, which formerly were carried toward the Center of the Earth by a ſecret Sympathy, in order to reſt quietly there, no more go or tend thither, but only as they are forced by the Efficacy of the fineſt Matter.

Eud. The ſubtile Matter which ſurrounds us, receiving two Directions, the one perpendicular to the Axis of the Earth, and the other horizontal or parallel, from the two Vortices which croſs one another, takes a middle Direction which carries it toward the Center, whither its Action thruſts the Bodies which it encounters. Such, you ſay, is the Cauſe of Gravity. For my Part, I believe that the Action of the Stars, whoſe Light ſtrikes our Eyes, and the Refractions which the ſubtile Matter ſuffers in the Atmoſphere, may contribute to that, and ſecond your Sentiment; the Hypotheſis is ingenious: but an ingenious Hypotheſis is an Hypotheſis in the Air, and falls to the Ground, if it do not explain the divers Effects of Gravity.

In a Tube hermetically ſealed, agitate and mix together pounded Glaſs, Oil of Tartar, Spirit of Wine, and Oil of Peter; then let them alone, and you will quickly ſee thoſe four different Species of Bodies diſintangled from one another, ſeparated, moved, and placed above one another, the Oil of Peter above the Spirit of Wine, the Spirit of Wine above the Oil of Tartar, and the Oil of Tartar above the pounded Glaſs. What is it that makes this Diſcernment? Muſt it ſtill be the ſubtile Matter? Would it ſeek out and diſintangle the Particles of every Species in order to unite them again, and place every Species exactly in its Rank?

Ariſt. The more Solidity Bodies have, the fewer are their Interſtices; the fewer Interſtices they have, the fewer free Paſſages they afford to the ſubtile Matter; the fewer free Paſſages they afford it, the more Blows they receive from it; the more Blows they receive from it, the more they are impelled towards the Center of the Earth; the more they are impelled towards the Center of the Earth, the more relative Weight they have; and in Proportion to their relative Weight, they are placed below others.

This being granted, the ſubtile Matter meeting with more Solidity in the pounded Glaſs than in Oil of Tartar, more in Oil of Tartar than in Spirit of Wine, more in Spirit of Wine than in Oil of Petre, ſtrikes, impels, and precipitates the pounded Glaſs more effectually than Oil of Tartar, Oil of Tartar than Spirit of Wine, and Spirit of Wine than Oil of Petre. Hence the pounded Glaſs is placed at the Bottom, and over the Glaſs Oil of Tartar, *&c.* as the Earth, by the ſame Reaſon, is placed immediately under the Water, the Water under the Air, and the Air under the Fire. Thus the ſubtile Matter, making Uſe of the Motion which it has received from God, and which he continues to it, and ſtriking divers Bodies more or leſs, according to the different Texture of their Parts, unravels a Chaos, and compoſes a kind of little World in a Glaſs-Tube.

Eud. You are going on to diſcover infallibly in your ſubtile Matter, why, the Bulk being ſuppoſed equal, Gold weighs more than Mercury or Quickſilver, Mercury more than Lead, Lead more than Silver, Silver more than Copper, Copper more than Iron, Iron more than Pewter, Pewter more than Marble, and Marble more than common Stones, *&c.*

Ariſt. The Texture of the Parts being more compact in Gold than in Mercury, in Mercury than Lead, in Lead than Silver, in Silver than Copper, in Copper than Iron, in Iron than Pewter, in Pewter than Marble, in Marble than common Stones, *&c.* the Gold receives more effectual Blows, more Force than Mercury, Mercury than Lead, *&c.* and it communicates and loſes leſs of its Force, having leſs Surface in Proportion to its Maſs. Hence Gold makes more Effort than Mercury, Mercury than Lead, *&c.* in order to withdraw itſelf from the Blows of the ſubtile Matter and to reach the Center of the Earth. Thus I think we have the Reaſon why Gold is heavier than Mercury, Mercury than Lead, *&c.*

Eud. You will have the Action of your imperceptible Matter, and the Texture of the Parts unequally compacted to make the Inequality of Gravity in Gold, Mercury, *&c.* But whence comes the Inequality of Velocity in the Fall of Bodies equally compacted, but of unequal Bulk?

Ariſt. Thoſe whoſe Bulk is greater, have leſs Surface in Regard of their Maſs; having leſs Surface they encounter, in their Fall, fewer Parts of Air to drive away in order to reach the Center whither they tend; meeting with leſs Obſtruction, they communicate leſs of the Force which they received from the ſubtile Matter; the leſs they communicate of it, the leſs they loſe; the leſs they loſe of it, the more they retain; the more Force they retain, the more ſwiftly they move. Thus you have the principle from which proceeds the Inequality of Velocity in the Fall of Bodies.

Eud. It ſeems, this Inequality of Velocity ought to be obſerved alſo in the Fall of the ſame Bodies, in the open Fields, and under a Vault.

Ariſt. Not at all; the Subtlety of the ſubtile Matter makes it find in a Vault Millions of free Paſſages in order to precipitate downward groſs Bodies with the ſame ſenſible Celerity, as in the open Fields; and this has nothing in it which ought to ſurprize a Philoſopher. Put a Plate of Copper between the Loadſtone and Compaſs. Make the Loadſtone turn about rapidly upon its Center. The Needle turns about with the ſame ſenſible Velocity, as if nothing had been put between it and the Loadſtone. What makes it turn round? Is it not the Action of an infinitely fine Matter, which comes out of the Pores of the Loadſtone, and paſſing through thoſe of the Copper, gives the

Needle, of itſelf indifferent and quiet, a circular Motion, which makes it ſearch out the Poles of the Loadſtone, that flies from it, with ſo much Inquietude and Celerity?

Eud. Plauſible Reaſons never fail you; but agree to it at laſt, that Bodies melted or calcined ought to weigh leſs than before. For after having loſt by the Violence of Heat, a Quantity of ſolid Particles which are exhaled in Smoak, they give leſs hold to the Strokes of the ſubtile Matter. Notwithſtanding, Lead and Pewter being melted, and *Regulus Antimonii* being calcined, far from loſing this Weight, acquire more.

M. Duclos of the Academy of Sciences reduced in a Marble Mortar, a Pound of *Regulus Antimonii* to Powder. This Powder they expoſed to the Rays of the Sun in an earthen Pot, and then they ſet Fire to it by Means of a burning Glaſs. A thick and whitiſh Smoak came out of it; and an Hour after the Powder was reduced into a ſort of Aſhes, which, notwithſtanding the Evaporation of a thick Smoak, was a tenth Part heavier than it was before[t]. *M. Homberg* made the ſame Experiment with the ſame Succeſs[u]. Bricks alſo become more weighty in the Fire[x].

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[t] Chimie de Lémeri, c. 5. Hiſt. de l'Acad. 1667. [u] Mem. de l'Acad. des Sciences, 1705, p. 94. [x] Bib. univ. & Hiſt. 1689, T. IX. p. 430.

Such Experiments ſeem made to take away from ſubtile Matter, light as it is, the Glory of cauſing the Gravity of Bodies.

Ariſt. Such like Experiments, in which ſubtile Matter itſelf has ſo great a Share, have nothing in them which ought to deprive it of the Poſſeſſion it has of the Power of fixing us here, at leaſt for ſome Time; without which the Curioſity of our Minds would make our Bodies travel into the Planets, before we attain to the Knowledge of the Earth itſelf. It is ſufficient for this Sort of Experiments, that a great Number of heterogeneous Parts, agitated in Bodies before melting or Calcination, are evaporated and diſſipated by the Heat; or that loſing by the exceſſive Agitation their Figure proper for Motion, they are intangled in one another, and fixed by the Inequality of their Particles, or by the Cold which ſucceeds the Heat. Being agitated before melting or Calcination, they ſupported and ſuſtained the ſolid Particles againſt the Strokes of the ſubtile Matter, and blunted its Force. Being diſſipated by melting or Calcination they ſupport them no longer. Being fixed they receive themſelves, without any Reaction, the Strokes which render Bodies heavy. The want of Motion, or Fixation of the heterogeneous Parts contributes more to the Weight than did the agitated Parts, which are evaporated and diſſipated. Hence this Exceſs of Weight in Bodies diminiſhed in their Maſs and Bulk. In ſhort, the

Weight of Orpine, which is a ſort of Colour for Painters, being fixed with Salt of Tartar is augmented a fifth Part; and any Body knows that cold Water is heavier than hot Water which is more agitated.

Does not this Reaſon ſatisfy? One may ſay that certain Corpuſcles of Sulphur happen to be attached to Bodies, which increaſe in Weight, while they are melting or calcining; Corpuſcles of the Colour of Aſhes have been ſeen attached to the *Regulus Antimonii* when inflamed[y], let it be the Air or Fire that furniſhes ſuch Sort of Corpuſcles.

Eud. You render whatever you pleaſe probable, and I muſt at laſt go into your Sentiment concerning the Cauſe of Gravity.

Ariſt. I believe, *Eudoxus*, it will not coſt you much to think upon this Head as I do; you know whence I have drawn what I have ſaid concerning it.

Eud. You imitate the Bees; you know how to improve and make your own what you find elſewhere.

Ariſt. Explain your ſelf upon the Rules of Gravity; and you will tell me Truths much more agreeable than all your Compliments.

Eud. To explain my ſelf upon theſe Rules, I ſhall firſt diſtinguiſh three Sorts of Centers; the Center of Bigneſs or Figure, the Center of Weight or Gravity, and the Center of heavy

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[y] Hiſt. de l'Acad. 1667. p. 14.

Bodies. I call the Center of Bigneſs or Figure, that Point in heavy Bodies which is equally diſtant from all the oppoſite Points of the Circumference. I call the Center of Gravity, that Point in a heavy Body which is ſituate after ſuch a Manner that the oppoſite Parts which ſurround it are in *Æquilibrium*, whether they be equally diſtant from this Point or not. Hence the Centers of Bigneſs and of Gravity are not always united in the ſame Point; they would not be ſo in a Ball half Iron, and half Ivory. Finally, the Center of heavy Bodies is a common Point whither thoſe Bodies tend, as of themſelves; ſuch is the Center of the Earth.

Imagine now a ſtrait Line drawn from the Center of Gravity, to the Center of heavy Bodies; this is called the Line of Direction, becauſe it directs, in ſome Sort, the natural Motion of heavy Bodies toward their common Center. Is a Body removed from this Center? It aſcends. Does it draw near it? It deſcends. This is ſometimes by a plane vertical or perpendicular to the Horizon, and ſometimes by an inclined Plane. This being granted, let us ſee Bodies deſcend, and we ſhall always find them faithful in obſerving certain Rules preſcribed by Nature.

Rule I. If the Center of Gravity cannot deſcend, the heavy Body does not deſcend. But whenever the Center of Gravity can deſcend, the Body deſcends; becauſe the

Parts, which are round about the Center, are in *Æquilibrium*, joined and faſtened in ſome Sort with the Center.

Rule II. Does the heavy Body deſcend freely? It never leaves the Line of Direction; why? Becauſe the Cauſe of Gravity, which gives it a perpendicular Direction, endeavours to maintain it therein, and no Reaſon removes it from it; the oppoſite Parts, which ſurround the Center of Gravity, being all in *Æquilibrium* by the firſt Rule.

Rule III. Is not the Deſcent perfectly free? The heavy Body moves as little as it can from the Line of Direction; ſince the Cauſe of Gravity gives it every Moment (by the ſecond Rule) a perpendicular Direction, which would carry it toward the Center by the Line of Direction, if no Obſtacle turned it aſide from this Line and the Center.

Rule IV. Should the Center of Gravity not be in the Center of Bigneſs, the firſt would always be loweſt when the Body deſcends; as it will always be higheſt when the Body aſcends; becauſe it being in that Caſe in the moſt ſolid Part, is alſo in a Part moſt proper for Motion.

Rule V. Let an heavy Body deſcend freely or not, by a vertical Plane, or an inclined one, its Motion is accelerated in the Fall; for being ſtruck by the repeated Blows of the ſubtile Matter, it acquires every Moment more Force than it loſes. Accordingly the Shock is augmented in Proportion to the Height from which a Body falls. But after what Manner is the Motion accelerated? It follows nearly the arithmetical Progreſſion of odd Numbers, 1, 3, 5, 7, *&c.* So that if in the firſt Inſtant it run through a Space of one Foot, in the ſecond it runs through about three Feet, in the third five, *&c.* according to the Obſervations of *Galilæus*, and Father *Sebaſtian*.

Thus according to the Experiment of Father *Riccioli*, a Ball of Wood, of an Ounce and a half, falling from the Height of thirty five Inches into one Scale, elevates a Weight of five Ounces put into the other Scale; from the Height of 140 Inches, a Weight of 20 Ounces; from the Height of 315 Inches, a Weight of 45 Ounces; and from the Height of 560 Inches, a Weight of fourſcore Ounces[z]. Therefore, *&c.*

In a Word, if by the Force acquired ſucceſſively in the firſt Inſtant the Body runs thro' one Foot, it ought, retaining almoſt the ſame Force, to run thro' about two Foot the ſecond Inſtant; ſince almoſt all the Force acquired in the firſt acts during all the ſecond. The ſame Body ought to run through one Foot more by the new Force which it acquires in the ſecond Inſtant. Therefore it ought to run through about three Foot in the ſecond Inſtant, and five Foot in the third by the ſame Principle, *&c.*

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[z] Aſtron. Ref. Journ. des Sçav. 24. *Jan.* 1667. p. 17.

Rule VI. When the Motion of a Body is accelerated to a certain Degree, it is accelerated no more; becauſe it then withdraws and ſnatches itſelf from the Strokes of the ſubtile Matter with ſo much Velocity, that it receives no more Impreſſion than is neceſſary for its deſcending by an uniform Motion with as much Celerity as the ſubtile Matter.

Rule VII. A Body which deſcends upon an inclined Plane, deſcends with leſs Celerity than on a vertical Plane: The vertical Plane does not ſuſtain it. It is in Part ſuſtained by the inclined Plane, which in ſome Meaſure renders the Force of Gravity uſeleſs. Thus the Stroke of a Body, which comes upon an inclined Plane to ſtrike you, hurts you more lightly, and ſo much the more lightly, as the Plane is the more inclined.

At the firſt Opportunity let us enliven our Philoſophy a little with reſolving ſome Problems, whoſe Solution ought to be the Conſequence of what we have both ſaid, in this Converſation.

CONVERSATION XVIII.

Wherein ſeveral Problems upon Gravity are reſolved.

Eud. WE know, that the Earth is ſpherical. Let us imagine it bored through from one Point of its Surface to the oppoſite Point; and let us place a Man in the Boſom of it. Let this Man have his Center of Gravity in the Center of heavy Bodies. Will he have Need of any Prop to ſupport him?

Ariſt. No certainly, ſince the Feet and Head will be equally propelled toward the Center. But whether will his Feet or his Head be uppermoſt?

Eud. Without his being crooked he will have both Feet and Head uppermoſt, ſince he will have his Feet and Head equally diſtant from the Center of heavy Bodies. But what Method would you take to make him aſcend and deſcend at the ſame Time?

Ariſt. Let him move his Head from the Center, his Feet will approach to it, and he will, in ſome Senſe, aſcend and deſcend at the ſame Time; ſince to approach to the Center is to deſcend, and to move from it is to aſcend. But I ſuppoſe that this Man having aſcended as far as the Surface of the Earth, is found amongſt the Antipodes. How does he remain attached like them to the Surface of the Earth, the Soles of his Feet being diametrically oppoſite to ours, and his Head elevated toward Heaven as we are.

Eud. This is becauſe the ſubtile Matter, which ſurrounds the ſpherical Earth, impels them as it does us, and gives them as well as us a perpendicular Direction toward the Center of heavy Bodies. But if the Cauſe of Gravity equally ſurround the whole Globe of the Earth, the Surface of Liquors ought to be convex; yet you would ſay that it is a Plane.

Ariſt. It is convex indeed, although its Convexity is inſenſible; for its Parts being equally preſſed toward the Center of the terreſtrial Globe, they ought all to approach it equally, and conſequently make an Arc, all the Points of which being equally diſtant from a common Center, compoſe a convex Surface. But if Bodies are thus preſſed every where toward the Center of the terreſtrial Globe, how are two perpendicular Walls parallel?

Eud. It being ſuppoſed that the Earth is round, they are not indeed really parallel; for if both the one and the other ſhould deſcend to the Center by a perpendicular Line, they would be united together. But if the Point of a Needle ſhould happen to be immovable in this perpendicular Line, what Weight could it ſuſtain?

Ariſt. Being placed below the Center of Gravity, it might ſupport an immenſe Weight; ſince upon this Suppoſition the Center of Gravity could not deſcend. But why does an immenſe Weight move without Difficulty divers Ways, when the Center of Gravity is ſuſpended in the Air?

Eud. Becauſe in that Caſe you have neither the Inequalities of a rugged Plane to deſtroy, nor the Force of Gravity to overcome. But what would happen, if the Center of Gravity were neither ſuſpended nor ſupported?

Ariſt. It is evident that it would fall; ſince the Cauſe of Gravity would puſh it downward, and nothing would hinder its Fall; and in its Fall it would carry along with it the reſt of the Body, according to your firſt Rule of Gravity.

Eud. You ſee, no doubt, in this Principle, why in the Motion of two footed Animals the Body inclines and is biaſſed ſometimes to the right, ſometimes to the left.

Ariſt. This is to the End that the Line of Direction always paſſing through one Foot, while the other is in the Air, the Center of Gravity, from which the Line of Direction proceeds, may be ſuſtained by this Foot. If the Center were ſupported by nothing, it would fall, and carry along with it the two footed

Animal,

Animal, whether rational or not, to the Ground. But pray, what is it that teaches the little Birds perched upon a Tree in the Night-Time to hold faſt the Branch preciſely with one Foot, to draw up the other Foot under their Feathers, to carry their Head on the other Side, and hide it under the Wing, in order to ſleep quietly?

Eud. It is Nature which teaches them, to the End that the Line of Direction may paſs through the Foot which graſps the Branch, and that the Center of Gravity, ſupported by this Foot, may not diſturb them, nor oblige them to interrupt their Sleep, and to fly away, in order to avoid falling.

Ariſt. It is Nature alſo then, which by ſecret Leſſons teaches Porters and crook'd-backed Perſons to bend themſelves forward, when they have a conſiderable Weight upon their Back; or to bend backward when they carry a Weight before them, as Perſons do who are in very good Plight of Body, or Women big with Child.

Eud. Nature makes them ſenſible that they ought to take this Situation, that the Line of Direction may paſs through the Legs, and that the Legs may ſupport the Center of Gravity; without which one might ſee frequent Falls more dangerous than diverting. But when good Manners incline the upper Part of the Body, and bow the Head forward, why does the natural Mechaniſm, as well as good Manners, advance one Foot?

Ariſt. They advance one Foot thro' which the Line of Direction may paſs, and which ſupports the Center of Gravity, leſt by an Exceſs of good Breeding one ſhould throw one's Face upon the Earth, as they infallibly do, who without any Support, having both their Feet againſt a Wall, attempt to take up a Pin, or gather a Flower at their Feet.

Nevertheleſs in a four footed Animal, in a Horſe for Example which gallops, the Center of Gravity being toward the middle of his Belly, ſeems to be ſuſtained by nothing, yet he does not fall. Why?

Eud. In a Horſe which gallops, the Center of Gravity, as well as the ſolid Diagonal wherein it is found, is ſuſtained by two Legs, the right Fore-leg, and the left Hind-leg; or by the left Fore-leg, and the right Hind-leg; ſince both the one and the other always bearing alternately upon the Earth, ſupport the ſolid Diagonal which goes from a right Leg to a left one, and to which the Center of Gravity correſponds.

Can you tell me with the ſame Facility why Bodies, whoſe Baſe is very large, can remain inclined with the greater Safety?

Ariſt. Becauſe while the Line of Direction paſſes through the Baſe, the Center of Gravity being ſupported by the Baſe cannot fall; and ſo long as it cannot fall, the Parts ſurrounding

rounding it remain faithfully attached to it, by the firſt Rule of Gravity. Hence the famous Tower of *Piſa*, whoſe inclined Top ſeems to threaten Ruin every Moment, always ſtands firm, and dares the Efforts of Gravity and Wind.

Eud. I adhere to your Sentiment upon this Head. But upon a Plane I give a right Direction to a Bowl, whoſe Center of Gravity does not coïncide with the Center of the Figure: Will the Bowl turn aſide or not?

Ariſt. It will turn aſide; for the half of the Bowl, in which the Center of Gravity is not, having leſs Maſs, will loſe more of its Velocity, and for want of Velocity will force the other half, which ought to move more ſwiftly, to turn aſide; much after the ſame Manner as the fixt Point, which is at the End of a *Radius* or Spoke, conſtrains the other Extremity every Moment to leave the right Line, in order to deſcribe the Arc of a Circle.

Let us ſuppoſe now that the Center of Gravity, and the Center of Bulk or Figure, are the ſame Thing in the roundeſt Bowl that can be made. I place it upon the Edge of an horizontal Plane perfectly ſmooth: What happens?

Eud. The Bowl, without your impelling it the leaſt in the World, will go as of itſelf, but is protruded by the ſubtile Matter, towards the Middle of the Plane; becauſe the Middle of the Plane will be neareſt to the Center of the

Earth. For all the Lines or *Radii*, from the Middle to the Extremities of the Plane, will be ſo many Tangents, which will remove more and more from the Center of heavy Bodies; ſo that if one ſhould walk upon this Plane from the Middle towards the Extremities, or from the Extremities towards the Middle, one ſhould deſcend or aſcend inceſſantly upon an horizontal Plane. This is my Anſwer, I wait for yours.

I throw a Cat from the third Story into the Street; the firſt Inſtant of its Fall it has its four Feet upward; yet it falls upon the four Feet without any Hurt. What is it that gives it ſo ſafe a Direction in the Time of falling?

Ariſt. That is what I would willingly learn from your Mouth.

Eud. The Cat being ſuddenly ſeized with a kind of natural Fear, bends the Back-Bone, advances the Belly, ſtretches out Feet and Head, as if it attempted to recover the Place whence it came; and this gives the Feet and Head the greater Force of a Leaver. In this extraordinary Motion the Center of Gravity aſcends above the Center of Figure; but not being ſuſtained it ſoon deſcends; in deſcending in order to place itſelf below the Center of Figure, according to the fourth Rule, it turns the Belly, Head and Feet of the Cat towards the Earth; ſo that at the End of the Fall the Cat finds itſelf at the Ground upon its four Feet, and only runs the more ſwiftly: Thus you have the Problem explained.

Now I fill a Pail with Water; I plunge a Staff into it, one of whoſe Extremities is in the Middle of the Bottom; between the other Extremity of the Staff and the Handle of the Pail I inſert the Blade of a Knife, which leans horizontally upon a Table or Plane: Will the Pail fall?

Ariſt. The Pail cannot fall, unleſs the Blade be inclined; the Blade cannot be inclined, unleſs the Staff in the Middle of the Pail deſcribe an Arc of a Circle, elevating its lower End toward the Table or Plane; the Staff cannot aſcend after that Manner, unleſs the Pail aſcend with the Water; the Staff, Pail and Water cannot aſcend, unleſs the Center of Gravity aſcend; the Center of Gravity cannot aſcend, ſince the Cauſe of Gravity thruſts it toward the Center of heavy Bodies, and no Force puſhes it backward: Therefore the Pail of Water will not fall.

You know better than I do, that the Pail will not fall: But do you know what Method muſt be taken to make a Bridge in the Air without Pillars, upon which one might walk without aſcending or deſcending, although in walking one always deſcribed an Arc of a Circle.

Eud. The Plan of that is very eaſie. Make a Vault of Stones in the Air, equally diſtant from the Center of the Earth, equally compreſſed

preſſed by the Cauſe of Gravity, and equally ſupported by one another. Let the Vault encompaſs the whole Earth, as the Ring of *Saturn* encompaſſes that Planet, and thus you have your Bridge in the Air: You may walk upon it without aſcending or deſcending, ſince you will always be equally diſtant from the Center of heavy Bodies.

Ariſt. The Walk would be new; but I ſhould find more Pleaſure in hearing you diſcourſe here of the Vibrations of the Pendulum, or of this Billiard-Ball ſuſpended.

Eud. Here is a Pendulum at Reſt in a perpendicular Line, or Line of Direction. I remove it from this Line, carry it to the Right, and then leave it to itſelf. The Gravity makes it fall, as it were by a ſort of inclined Plane. In its Fall it accelerates its Motion (by the fifth Rule of Gravity). Having by that Means acquired more Force than is neceſſary for regaining the Line of Direction, from which I removed it, it paſſes beyond it and aſcends to the left, ſo long as its acquired Force can overcome the Reſiſtance of the Air and of Gravity. In aſcending to the left, it deſcribes a ſmaller Arc, than in deſcending, becauſe it meets with more Reſiſtance. In deſcending, it had only the Air to drive away; in aſcending, it has both the Air to repel, and the Gravity to overcome. Being forced to yield, it falls back from a leſs elevated Part than the firſt Time; it again accelerates its Motion proportionally, and paſſes beyond the Line of Direction. Having fallen back from a leſs elevated Place, it aſcends ſtill to a leſs Height, becauſe it has acquired leſs Force. It falls back ſtill, being impelled by the Cauſe of Gravity; and by alternate Vibrations, which continue to diminiſh, it paſſes and repaſſes the Line of Direction, till, after having moſt exactly obſerved your Rules of Motion and Gravity, it reſts at laſt in the Line of Direction, from which I withdrew it at firſt.

The Vibrations of the ſame Pendulum, whether greater or ſmaller, always happen in equal Time, at leaſt in the Judgment of the Senſes. Remove two equal Pendulums unequally from the Line of Direction; then leave them at Liberty; you may ſee them form the ſame Number of Vibrations in the ſame Space of Time. Whence can that proceed? Becauſe the ſame Pendulum, when it makes greater Vibrations, makes them proportionally with greater Velocity. In a Word, it deſcends from a greater Height, and deſcribes an Arc which approaches nearer to the perpendicular, and conſequently it deſcends more ſwiftly, accelerates its Motion, and runs through a greater Space in the ſame Time. Hence the Vibrations of the ſame Pendulum, whether greater or ſmaller, are ſenſibly formed in equal Times; and Clocks with a Pendulum, or which have a Balance, are the moſt exact; becauſe all the Vibrations of the Balance or Pendulum being of the ſame

Duration, they are fitteſt for dividing the Time into equal Parts. Thus nothing is more exact than the Clock, which you ſee in my Cloſet. Its Motion however ſeems to me too precipitate to Day; becauſe it admoniſhes me to finiſh a Converſation, in which I find the moſt exquiſite Pleaſure. But at laſt, after what we have ſaid, one may eaſily comprehend what reſpects Gravity and its Effects. Mechanics have already ſhewed them us in ſolid Bodies, when we were ſpeaking of the general Principle of Mechanicks; whenever you pleaſe we will ſee them in liquid Bodies. I ſhall be pleaſed firſt to know your Opinion concerning Liquidity, and then I ſhall tell you mine concerning the Gravity of liquid Bodies, and laſt of all we ſhall diſpute concerning the *Æquilibrium* of Liquors.

CONVERSATION XIX.

Upon the Nature of liquid Bodies.

Eud. WHAT is a liquid Body? What is Liquidity? What is the Cauſe of it? You are going, *Ariſtus*, to clear up this Matter, and my greateſt Pleaſure is to ſee the Truth come from the Mouth of a young Perſon, who diſcovers ſo conſtant a Zeal for it in a Time and Age, wherein Fables have ſo many Charms.

Ariſt. Upon this Head I ſhall only tell you the Opinion of *Eugene*. I call a liquid Body, ſaid he to me yeſterday, a Body whoſe Parts yield, without any ſenſible Reſiſtance, to the Effort which I make in order to ſeparate them, and which takes all Sorts of Figures without any Difficulty †. Such are the Air, Water, Brandy, Wine, Milk, &c.

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† A Fluid is a Body whoſe Parts yield to any Force impreſſed, and by yielding are very eaſily moved one amongſt another. Whence it follows, that *Fluidity ariſes from this, That the Parts do not ſtrongly cohere, and that the Motion is not hindered by any Inequality in the Surface of the Parts,* as it happens in Powders. But the Particles of which Fluids conſiſt, are of the ſame Nature with the Particles of other Bodies, and have the ſame Properties; for

What is Liquidity then? It is, continued he, a continual Agitation of inſenſible and divided Parts; ſuſpend this Agitation, and the liquid Body is hardened; by that Means Water becomes Ice in Winter. Reſtore this Agitation to the inſenſible and divided Particles; the leaſt Effort ſeparates them; no more is required but to give them new Directions: Thus the hard Body becomes liquid, and Ice is no longer any Thing but Water.

Thus Experience ſufficiently diſcovers a continual Agitation of inſenſible Particles in Liquids. For in a Word, Sugar and Salts are diſſolved in Liquors, and Liquors receive the Colour, Taſte, and ſpecific Virtues of Barks and medicinal Plants. This is not done but by the Diſorder and local Tranſportation of their Particles. The inſenſible Particles of Liquors cauſe this Diſorder and Tranſlation; they only cauſe it by Motion; they only give their own Motion in order to cauſe it: Therefore they muſt be in a continual Agitation. Hence

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for Liquids are often converted into Solids, when there is a more ſtrong Coheſion of them, as in Ice. On the contrary melted Metals give us an Inſtance of a Solid changed into a Fluid.

Fluids agree in this with ſolid Bodies, viz. *That they conſiſt of heavy Particles, and have their Gravity, proportionable to their Quantity of Matter in any Poſition of the Parts.*

If in the Liquid itſelf that Gravity be not ſenſible, it is owing to this, that the lower Parts ſuſtain the upper, and hinder them from deſcending: But it does not follow from thence, that the Gravity is taken away; becauſe a Liquid contained in a Veſſel will preſs down the End of a Ballance, which carries the Veſſel in Proportion to its Quantity. *Vide Graveſande,* p. 133.

the Mixture of Wine and Water is made with ſo much Quickneſs, that you would believe the Water ſuddenly changed into Wine.

But whence proceeds, demanded I, this continual Agitation of inſenſible Particles? In a Word, what is the Cauſe of Liquidity? I ſee two Cauſes of it, anſwered *Eugene*; the one internal, and the other external. I find the firſt in the cylindrick, elliptick, or ſpherical and poliſhed Figure of the Particles of liquid Bodies; and the ſecond in the rapid Motion of the ſubtile Matter, which meeting in its Way with Particles of a Smallneſs and Figure ſo ſuſceptible of Motion, communicates it to them inceſſantly; without which the Air itſelf, which encompaſſes us, would in a ſhort Time become a ſolid Body, wherein every one would be much aſtoniſhed to ſee himſelf immovable, as in a ſort of Niche or Hole.

Therefore, ſaid he again, it is the ſubtile Matter which gives Liquors the Efficacy they have in diſſolving ſo many ſolid Bodies. But why does not this matter diſſolve them equally without Liquors? Without Liquors, replied *Eugene*, this Matter, by Reaſon of its extreme Smallneſs, finds in thoſe Bodies too free Paſſages, and paſſes through without diſordering or hurting any Thing, at leaſt ſenſibly; or being too feeble for making itſelf a Paſſage, it turns aſide without doing any Damage. But in Liquors, it is charged with an Infinity of groſſer and more ſolid Particles; being charged after that Manner, it makes a Bulk which finds leſs Acceſs into the Pores, unites more Forces, ſtrikes more violently, ſhakes and breaks the Bonds which hold the Parts united together, and at laſt diſſolves the ſolid Bodies, ſo as to reduce them to a Liquor. Thus Water alone paſſes rapidly under a Bridge, and is broken againſt a Bark, without damaging either the Bark or Bridge; but is it charged with groſſer Bodies, Pieces of Timber on Shoals of Ice? It ſhatters the Bark, overturns the Bridge, and carries Deſtruction and Deſolation every where.

According to your Principles, replied I, all Bodies ought to be changed and corrupted ſooner in Liquors than in the Air. Nevertheleſs Cherries, Nuts, Apricocks, and Citrons are leſs preſerved in the Air than in *Aqua Vitæ* and diſſolved Sugar.

If the Liquor, anſwered *Eugene*, cannot, becauſe of its Thickneſs or Figure, penetrate into the Pores of a ſolid Body, it cannot diſſolve it; it only preſerves it from the Impreſſions of the external Air, and maintains it againſt the Efforts of the internal Air, which continually endeavours to break by its Spring, the ſmall Pores which retain it as it were impriſoned in the ſolid Body. Is the Liquor filtred too eaſily in a Body? It breaks few Bonds, Parts or Fibres; it cauſes little Alteration in it. When it inſinuates itſelf into the Interſtices charged with Salts, and thoſe Salts find themſelves intangled in them like ſo many ſmall Wedges, without being able to diſengage themſelves, by Reaſon of the Solidity of the Parts which ſurround them; theſe ſmall Wedges only give Conſiſtence to the Parts which contain them, and which they contain in ſome Sort; they hinder the fine Particles of the Liquor from dividing thoſe of the ſolid Body, or the Spring of the internal Air from breaking them. By that Means theſe Salts preſerve Fruits, as common Salt preſerves Meat.

This being granted, the Brandy penetrates too eaſily, or does not ſufficiently penetrate certain Bodies, ſo as to damage them: If it contains Cherries, Nuts, Apricocks, or Citrons with Sugar, it carries the Salts of the Sugar into an Infinity of Pores; thoſe Salts being ſunk like ſo many ſmall Wedges, without being able to extricate themſelves, only ſerve to give Conſiſtence to the Parts, which are between them; they ſecure them from the Action of the ſubtile Matter, Air and fine Parts of the Liquor. Thus Confits of Cherries, Nuts, Apricocks, and Citrons, are preſerved in Liquor; they loſe nothing in it but their Bitterneſs; the Liquor only ſweetens them; being imbibed with Salts, which ſtrike the Palate agreeably; far from being corrupted, they are rendered only the more delicious, the moſt rigid Philoſophers themſelves being Judges.

Your ſweet Meats, replied I ſmiling, appear to me to have an exquiſite Reliſh; I love them ſo much the more, becauſe you have, as it were, ſeaſoned them with Philoſophy. But a certain Quantity of Water diſſolves preciſely a certain Quantity of common Salt. The ſame Quantity of Water will however diſſolve ſtill a determinate Quantity of Sugar. How is this Problem explained upon your Principles? 1. The Particles of Water, anſwered *Eugene*, by their Agitation drive and expel from the Interſtices or Pores of different Salts the Air and ſubtile Matter; they penetrate into them as ſo many ſmall Wedges, divide, break and diſſipate the Parts. Here is the Secret of diſſolving. 2. The ſame Quantity of Water only diſſolves a certain Quantity of common Salt. Why? Becauſe the Points of the Water being blunted, by Means of their ſtriking againſt the Parts of this Salt, find no more Acceſs into its Pores. 3. The ſame Water does not yet ceaſe to diſſolve a determinate Quantity of Sugar. Here is the Reaſon: The Particles of Water, tho' their Points be blunted by diſſolving the Salt, are ſtill fine enough for entering with ſome ſort of Violence into the Interſtices of the Sugar, whoſe Pores are larger: But as they are blunted more and more, they become too thick for penetrating into the Sugar; and the Sugar receives no more impreſſion from them. Here is, I think, the Solution of the Problem.

But, replied I, ſome Uneaſineſs always accompanies Curioſity. I don't know if I ſufficiently underſtood from thoſe Principles how liquid Bodies ſometimes loſe their Liquidity; why, for Example, Blood let out of the Veins ſettles and coagulates. The Liquidity ceaſes, ſaid *Eugene*, in Proportion as the Motion ceaſes, and the Motion is loſt either by the Evaporation of the fineſt Parts, or by the Communication, or Mixture of certain Bodies, which by their Figure graple, faſten, and retain the agitated Particles of liquid Bodies. Is the Blood let out of the Veins? The fineſt Parts evaporate, and others communicate their Motion to the Air; the Air is full of Spirits of Nitre, which creep into the Blood, contract its Parts, and dull their Motion. Thus the Motion is loſt; the Blood, which carried Life into the whole human Body, thickens, coagulates and ſettles; thus it is uſeleſs. *Eugene*'s Sentiment concerning Liquidity ſeems to me too natural not to be adopted.

Eud. I adopt it as well as you, and nothing agrees better with my Opinion concerning the Gravity of liquid Bodies. Some Propoſitions will expreſs my Sentiments upon this Head the firſt Opportunity.

CONVERSATION XX.

Upon the Gravity of liquid Bodies.

Ariſt. YOU had the Patience to hear me laſt, *Eudoxus*; I will have the Pleaſure of hearing you to Day. Do not fear being interrupted.

Eud. Your Eagerneſs, *Ariſtus*, animates me to explain my ſelf.

PROPOSITION I.

" Liquors weigh ‡; ſince they afford ſome
" Hold to the Cauſe of Gravity, or to the
" Strokes of the ſubtile Matter, which thruſts
" them, and gives them its Direction toward
" the Center of the Earth.

By the ſame Principle the Air itſelf ought to have Weight, but leſs than ſenſible Liquids.

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‡ Fluids agree in this with Solids, *viz.* That they conſiſt of heavy Particles, and have their Gravity proportional to their Quantity of Matter, in any Poſition of the Parts.

PROPO-

PROPOSITION II.

" In Liquors, the Weight of the ſuperior " Parts is communicated to the inferior Parts ||.

Thoſe being impelled by the Cauſe of Gravity ought to impel theſe.

PROPOSITION III*.

" If the Imagination divide Liquors of the " ſame Species into Parts, Beds, or Surfaces of " the ſame Bulk; thoſe Parts, Beds, or Sur- " faces weigh proportionally as they are farther " diſtant from the ſuperior Surface, and nearer " the Bottom.

Becauſe in Proportion as they are nearer the Bottom, and farther diſtant from the ſuperior Surface, beſides the Impreſſion which they always receive immediately from the ſubtile Matter, they are thruſt towards the Center of heavy Bodies by the greater Number of heavy Parts, which cannot paſs through freely, where the ſubtile Matter alone would paſs, without making ſome Effort.

|| The lower Parts ſuſtain the upper and are preſſed by them, and this Preſſure is in Proportion to the incumbent Matter, that is, to the Height of the Liquid above the Particle that is preſſed; but as the upper Surface of the Liquid is parallel to the Horizon, all the Points of any Surface, which you may conceive within the Liquid parallel to the Horizon, are equally preſſed.

* See Note on PROP. II.

Thus Sea Water is ſo much the heavier, the more it approaches the Bottom. They faſten to a ſounding Lead, which is of a conſiderable Weight, and faſtened to the End of a very long Cord; they faſten I ſay, to the ſounding Lead a Glaſs Bottle, cylindrical, oval or round, empty, ſtopped with a ſealed Stople of *Spaniſh* Wax, and cloſed up with all poſſible Exactneſs. The empty Bottle, carried along by the Weight of the Sound, deſcends into the Depths. Draw it up again, and you will be ſurprized to ſee, at leaſt ſometimes, the Bottle almoſt full of clear Water extraordinary ſaltiſh[a]. How did this Water, clear and ſo ſaltiſh, enter into the Bottle? Becauſe the Bottle by Means of its deſcending, has been found in Beds ſo weighty, that in the exceſſive Compreſſion a Quantity of fine, but ſolid Parts of Salt have made a Paſſage for themſelves through the Pores of the Bottle, and thoſe Points of Salt have carried off into the Bottle a Quantity of Particles of Water, ſtrictly faſtened and united with them.

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[a] I ſaw a Perſon who made this Experiment. The Bottle had deſcended about 200 or 225 Fathoms.

PROPOSITION IV.

“ Divide Liquors into liquid Columns, uniform and perpendicular: The abſolute Weight of every Column will anſwer to its Height.

It is ſo much the greater, the higher it is; the higher the Column is, the greater Number has it of Parts or Beds; and by the third Propoſition every Part, every Bed weighs more in Proportion as it is farther diſtant from the ſuperior Surface, and nearer the Baſe.

Ariſt. Well, for once, *Eudoxus*, I ſhall have the ill-natured Pleaſure of ſurprizing you in a Fault. From a Tube quadruple in Height, and full, there would flow in an equal Time a quadruple Quantity, or four Times more Liquor; ſince the Cauſe of the Flux, or the Gravity would be quadruple, and the Effect anſwers to the Cauſe which produces it. Nevertheleſs from a quadruple Tube, there only iſſues out in an equal Time a double Quantity, or twice as much Liquor[b].

Eud. 'Tis true, there iſſues out only a double Quantity; but the Effect is nevertheleſs quadruple, as its Cauſe is. For a double Quantity of Liquor does not flow in equal Time, but with double the Velocity; and the flowing of a double Maſs with double the Velocity is a quadruple Effect. This Flowing, this Effect, is the Motion which reſults from two Degrees of Maſs, and two Degrees of Velocity; and this Motion is four Degrees, ſince Motion is meaſured both by the Velocity and the Maſs, and is the Product of the one multiplied by the other.

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[b] Hiſt. de l'Acad. An. 1668.

Should a Force of one Degree make one Inch of Water iſſue out in an Inſtant, a Force of four Degrees will only make two Inches run out in an Inſtant; for two Inches of Water flowing in an Inſtant, and conſequently with a double Velocity, or two Degrees, afford four Degrees of Motion, if you multiply them by one another; and theſe four Degrees of Motion are an Effect which anſwers to a Force of four Degrees.

Ariſt. If a Force of one Degree make an Inch of Liquor run out of a Tube in an Inſtant, is it not natural that a Force of four Degrees make four Inches run out in an Inſtant?

Eud. Not at all. A Force of four Degrees would produce an Effect of 16 Degrees; for the four Inches of Liquor would not iſſue out in an Inſtant, but with a Velocity of four Degrees, which multiplied by the four Inches of Liquor, would afford 16 Degrees of Motion. But a Force of four Degrees does not produce an Effect of 16 Degrees; the Force or Cauſe is not leſs than its Effect. Therefore though a Force of one Degree make an Inch of Liquor run out of a Pipe in an Inſtant, it is not natural that a Force of four Degrees make four Inches of it run out in an Inſtant. After this you may give your ſelf up to the ill-natured Pleaſure of ſeeing me in an Error.

Ariſt. I love better to indulge the Pleaſure of ſeeing at laſt why I was deceived.

Eud. Let us go on to explain my Sentiment.

PROPOSITION V.

" While the abſolute Gravity of the Co-
" lumns of a Liquid makes them tend down-
" ward, all their inſenſible Parts thruſt one
" another every Way, toward all the imagina-
" ble Parts of the Univerſe *.

For, 1. The Motion or Agitation, which makes the Liquidity of liquid Bodies, forces their inſenſible Parts to thruſt one another after that Manner. 2. The inferior Parts being compreſſed by the Weight of the ſuperior, like

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* *The Preſſure upon the lower Parts, which ariſes from the Gravity of the ſuperincumbent Liquid exerts itſelf every Way, and every Way equally.*

Which follows from the Nature of a Liquid, for its Parts yield to any Impreſſion, and are eaſily moved; therefore no Drop will remain in its Place, if whilſt it is preſſed by a ſuperincumbent Liquid it is not equally preſſed on every Side; But it cannot be moved on Account of the neighbouring Drops, which are preſſed in the ſame Manner, and with the ſame Force, by the ſuperincumbent Liquid; and therefore the firſt Drop is at Reſt, and equally preſſed on all Sides, that is, in all Directions.

Corol. Hence it follows, that *all the Particles of Liquids* are preſſed equally on all Sides, and therefore *are at Reſt*; and that they do not continually move among themſelves, as ſeveral have ſuppoſed. *Graveſande's Elem.* V. I. p. 136.

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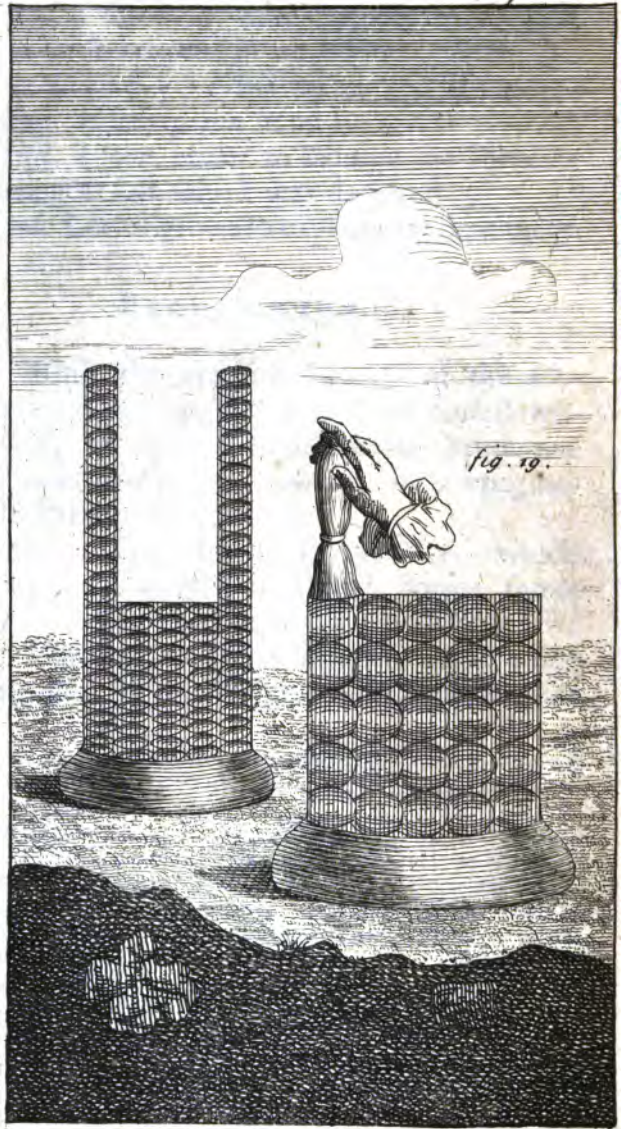

fig. 19.

ſo many little Balls full of Air, and contracted by a foreign Force, inceſſantly endeavour to extend themſelves, and by the Efficacy of their Spring thruſt the adjacent Parts on all Sides, *Fig.* 19. Hence,

1. Pierce the right or left Side of a Caſk, and the Wine will flow immediately. The Reaſon is not becauſe its Confinement in the Caſk is troubleſome to it; it finds itſelf no better in Mens Bodies than in the Caſk; the Caſk preſerves it, and Mens Bodies corrupt it. What is it then that determines it to flow? It is the univerſal Impreſſion of its Parts; thoſe Parts being impelled to the right and left, not only by their Motion of Liquidity, but alſo by the Spring of the internal Air, and by the Preſſure which proceeds from the Gravity, and being always ſubject to follow the third Rule of Motion, are darted into the Air, becauſe there they find leſs Oppoſition to their Direction.

2. Should a Dyke happen to be broke down, the Water of a River is turned aſide, and leaves its Channel by the ſame Reaſon; the Water of a Pond which appeared immovable, is ſpread abroad in great Surges as of itſelf, overflows the Fields, and carries either Devaſtation or Fruitfulneſs round about.

3. Should a lively and clear Water, which ſprings out of the Brow of a little Hill, or from the Top of a Mountain, come by ſubterraneous Channels to embelliſh our Gardens; whenever it is at Liberty, you may ſee it ſpring

up into the Air. The Action of Gravity made it at firſt deſcend from its Source; ſince its Parts being compreſſed by the Action itſelf of Gravity, and impelled a Thouſand Ways, follow the Direction of Channels parallel to the Horizon, and where the Reſiſtance is leaſt, till at laſt finding a free Paſſage, but exactly in a perpendicular Direction, they lay hold on it by the ſame Principle: And as by the fourth Propoſition they have a Force proportional to the Height of the Water which deſcends and preſſes them by its Gravity, they are rapidly darted into the Air; one would think they endeavoured to join their Source again; at leaſt they want but little of reaching the Level.

Ariſt. But why does not Water riſe as far as the Level itſelf of its Source?

Eud. 1. The Water loſes of its Force in the Channels by Friction. 2. When it ſprings up, the Reſiſtance of the Air divides its Parts; its Parts being divided, have thereby a larger Surface in Proportion to their Maſs; having a larger Surface they meet with more Air in their Direction, and loſe ſo much the more of their Force, the more they are obliged to divide it.

3. The Water which ſpouts up, falls back upon that which follows it, and weakens it by its Fall; and this hinders it from recovering the Level of its Source.

Would you be ſurprized now to ſee a Diver walk compoſedly to the Bottom of the

Sea, as we do here, in Order to ſeek Pearls, and to caſt his Eye upon all that is round about him without feeling the Weight of the Water, even when he happens to be under a Veſſel of a hundred Guns, and of a Crew of five Hundred or a Thouſand Men †?

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† The Cauſe of this is excellently well explained by *Jo. Alph. Borellus de Motibus Natur. in Gravitate factis. Prop.* 29, &c. After he had ſhewn, that Sand in a very ſtrong Veſſel, cannot any Way be divided, and that a Wedge will by no Means enter into it; and alſo that Water in a Bladder, equally compreſſed on all Sides, can neither be ſtreightened nor bent, nor at all moved: *So likewiſe,* ſays he, *in the Body of an Animal, there is contained within the Skin, ſome Parts which are hard and ſolid, ſuch as the Bones; others that are ſoft, ſuch as the Tendons, Nerves, Membranes and Muſcles; and others that are fluid, watry or oily. Now the Bones in an Animal cannot be broken or diſjointed, unleſs the incumbent Weight preſſes one Way only, as it does on Porters: But if the Preſſure diffuſes itſelf all round, ſo as to preſs upwards and downwards, and ſideways, with equal Force, ſo that there be no Part of the Skin but what is preſſed, then it is impoſſible, that any Thing ſhould be ſeparated or put out of the Way. The ſame may be ſaid of the Nerves and Muſcles, which though they be ſoft, yet becauſe they conſiſt of tough and ſtrong Fibres, they can all ſupport one another, and reſiſt an univerſally diffuſed ſpherical Compreſſion; the ſame may alſo be ſaid of the Blood and other Humours of an Animal, which are of a watry Nature; for as it is evident, that Water cannot be condenſed, ſo likewiſe the Humours of an Animal, contained in the Cavities of its Veſſels, though they may be bruiſed by an Impulſe made from one or a few particular Places; yet they can never be forced out of their Veſſels, or torn aſunder by an univerſal Compreſſion every Way. So long therefore as the ſolid, tendinous, or fleſhy or liquid Parts, do not undergo any Separation, Contuſion, nor are diſjointed, nor their Situation at all changed; it is impoſſible, that any Pain or Uneaſineſs ſhould follow in the Animal, which cannot ariſe from any other Cauſe, but ſeparating that which was one continued Thing. Wherefore when Divers,* &c.

And this is confirmed by what the famous Mr. *Boyle* obſerved, in *his ſecond Appendix to the Eleventh Hydroſtatic Paradox, viz.*

Ariſt. According to the Laws of the Union of the Soul and Body, we only feel Things in Proportion to the Changes which they produce in the Body, or in the Senſes. Now the Water produces no Change, at leaſt no conſiderable one, in the Body or Senſes of the Diver. The Parts of the Water being thruſt toward all imaginable Places, equally, or almoſt equally, puſh all the Parts of his Body toward a common Center; which Parts being diſpoſed in Form of a Vault, and ſupported by the inter-

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That a Tadpole, an Animal whoſe Fleſh is very tender and ſoft, put into a Veſſel half full of Water, ſo cloſed up, that the Air contained in it, being condenſed eight Times as much as in its natural State, preſſed upon the Water as much, as if a Column of Water of three hundred Feet in Height laid upon the Animal; moved itſelf notwithſtanding, and ſwam about very quick, and found no Inconvenience that could be perceived.

However, becauſe in moſt Animals there is a great deal of Air, which may eaſily be compreſſed and condenſed; therefore, though no particular Member is disjointed, when an Animal is immerſed very deep in Water, yet they muſt all of them neceſſarily be ſtraightened and contracted, by the equal Weight and Preſſure of the incumbent Water on all Sides, as Mr. *Boyle* ſays, happened to the Tadpole in the forementioned Experiment.

Beſides, thoſe Animals, whoſe Lungs are ſo formed as to contain a great deal of thin Air and Breath in them, though the other Parts of them be not at all hurt, yet their Breaſts muſt of Neceſſity be ſtraightned and contracted, in the ſame Manner, as the Cork is uſually thruſt into an empty Bottle, by the Weight of the Water, when it is ſunk very deep. Therefore Men, whoſe Lungs are very large, when they dive very deep into the Sea, though they find no Manner of Inconvenience in any other Part of their Bodies, yet they labour under a Difficulty of Breathing, and a Pain in their Breaſt (though they have Air enough conveyed to them to breath). And thus the famous Mr. *Boyle* tells us of a certain Diver, that when he walked at the Bottom of the Sea, the Blood flew out at his Noſe and Eyes. *Clarke's Rohault*, Vol. I. p. 59.

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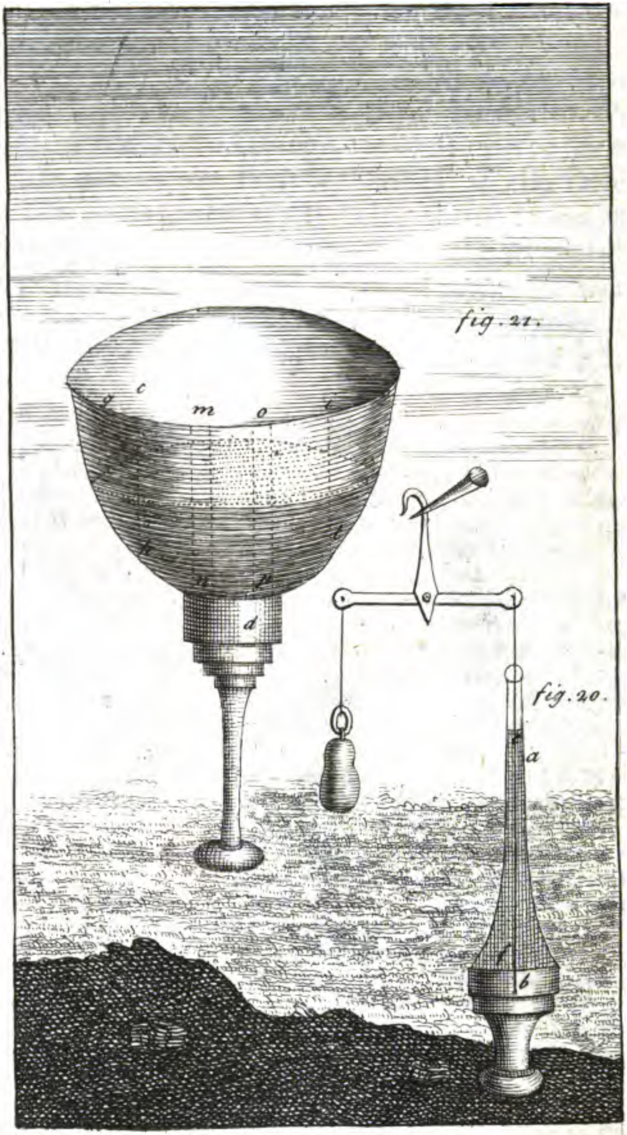

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nal Air, ſuſtain the equal, or almoſt equal Effect of the Parts of the Water, without being diſplaced or diſordered in any ſenſible Manner. Therefore I ought not to be ſurprized that the Diver feels not the Weight of the Water. You have indeed deprived me of the Pleaſure of a Surprize, by giving me one more agreeable.

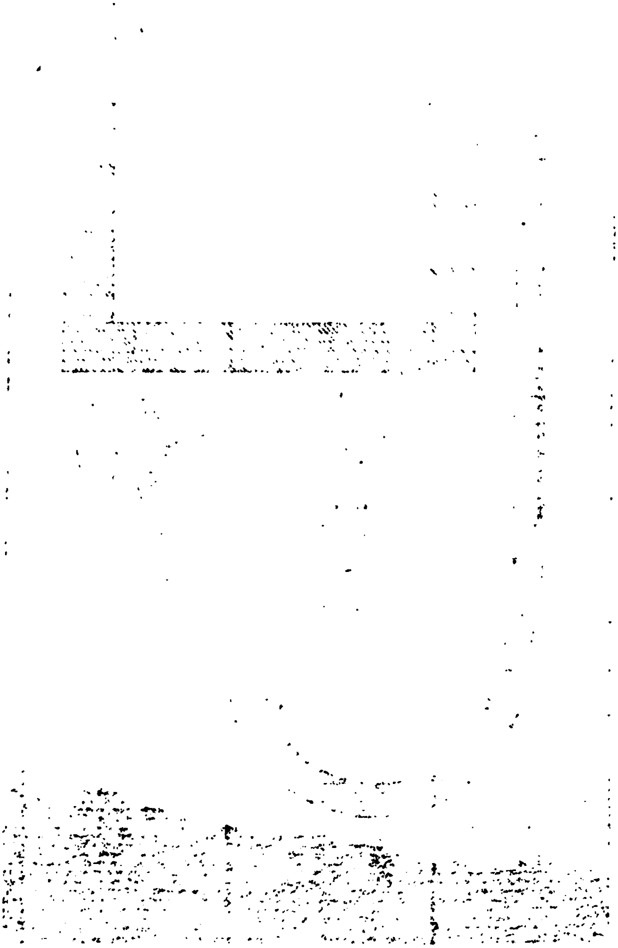
Eud. You readily conceive my Meaning.

PROPOSITION VI.

" A liquid Body weighs upon its Baſe according to its Height. The Impreſſion of a liquid Body upon the Baſe that ſupports it, although its Parts act with an univerſal Motion, anſwers preciſely to its Height and Baſe.

The Propoſition is true, if when there is the ſame Species of Liquor, an equal Baſe and equal Height in the liquid Body, the Action of the Gravity upon the Baſe, is equal notwithſtanding the Inequality of Size: But it is equal; it is, I ſay, equal if in a conic Veſſel *(a) Fig.* 20. which only contains one Pound of Water, the Action of Gravity upon the Baſe *(b)* is as ſtrong as in the wide Veſſel *(c) Fig.* 21. which carries 100 Pound of Water, upon an equal Baſe *(d)*, and under the ſame Height. It is demonſtrated by Reaſon, that the Action of Gravity upon the Baſe is equally ſtrong in thoſe two Veſſels; for the Parts, which immediately touch the Baſe of the conic Veſſel, cannot be of the ſame Number and equally compreſſed, without the Action of Gravity be equal; being of the ſame Number and equally compreſſed, they ought to make the ſame Effort to get more Room, and conſequently to preſs the Baſe alike. But 1. They are of the ſame Number, ſince by Suppoſition they cover equal Baſes. 2. They are equally compreſſed; for in the conic Veſſel there is at leaſt one Column of Water of the Height of the wide Veſſel; this Column has its Parts as much contracted as thoſe of the larger Veſſel, ſince the Preſſure of a Column of Liquor anſwers to its Height by the fourth Propoſition. Its Parts being equally compreſſed, make the ſame Preſſure to paſs into the Columns which ſurround it, ſince they act with an univerſal Motion by the fifth Propoſition, and alſo with all their Forces, as all neceſſary Cauſes do. The Action of Gravity upon the Baſe is therefore equal in both Veſſels.

In ſhort, if the two equal Baſes of two Veſſels, equal in Height, but unequal in Wideneſs, are two moveable Piſtons (*b*, *d*), Experience ſhews, that to ſupport the Piſton, which has in it only one Pound of Water in the conic Veſſel, as much Force is required as to ſuſtain the Piſton which bears an hundred Pound in the other Veſſel much larger. Therefore when there is the ſame Species of Liquor, an equal Baſe, and an equal Height of the liquid Body, the Action of Gravity upon the Baſe is equal;



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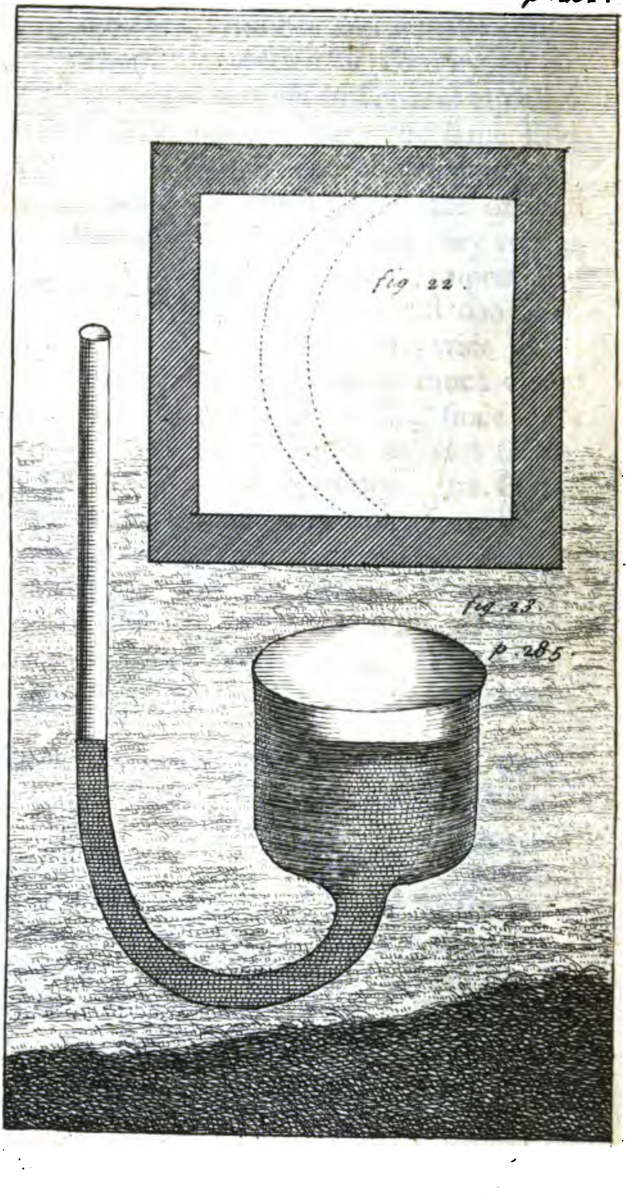

equal; therefore the Impreſſion of a liquid Body upon the Baſe which ſuſtains it, though its Parts act every Way, anſwers preciſely to the Height and the Baſe; which was to be proved.

But, you will ſay, in the Veſſel which widens continually, the lateral Columns of Water *(gh, il)* ought to act upon thoſe which are perpendicular to the Baſe *(mn, op)*. It is true; but by the ſame Principle there is an equal Reaction on their Part: Hence the oblique Effort of the lateral Columns does not paſs to the Baſe.

Ariſt. But when the Baſe of a conic Veſſel is immovable, in ſupporting it I only find in the Water the Weight of one Pound. Let the ſame Baſe become moveable, and I find a Weight of an hundred Pound in the ſame Quantity of Water. What Charm changes at once the Weight of one Pound into the Weight of an Hundred?

Eud. In order to diſcover this ſecret Charm, I ſuppoſe a Bow *(a) Fig.* 22. whoſe abſolute Weight is one Pound, and whoſe Spring is equal to the Weight of an Hundred. I bend this Bow and place it in a Machine between two Planes, joined in ſuch a Manner, that it cannot ſeparate them. After that I ſupport the inferior Plane with the Hand, and I only find in the Bow the Weight of one Pound, I feel only the abſolute Weight of the Bow. Why? While the bent Bow endeavours by the Force of its Spring to ſeparate equally the two inſeparable Planes, by the Effort which it makes againſt the upper Plane, it thruſts the lower Plane back as much toward the Sky, as it puſhes it toward the Center of the Earth. For which Reaſon the Force of the Spring deſtroys itſelf in ſome Sort, with Reſpect to the Hand which ſuſtains the Plane. Being thus deſtroyed, it is not perceived, and ſpares me the Trouble of ſuſtaining a Force of an hundred Pound Weight. But is the lower Plane ſuddenly detached? The Force of an hundred Pounds, which by Means of the Machine equally impelled it toward two oppoſite Points, now preſſes it only toward my Hand; and at once I have the Weight of an hundred Pounds to ſuſtain.

Now the ſmall Parts of Water in the conic Veſſel are ſo many ſmall bended Arcs, one Extremity whereof reſts upon the Baſe, while the other is ſupported upon the inclined Sides of the Veſſel. Is the Baſe attach'd to the Sides of the Veſſel? The Spring of thoſe ſmall Arcs puſhes the Baſe by the Effort which it makes immediately againſt it, and puſhes it back by the Effort which it makes immediately againſt the inclined Sides of the Veſſel. Being impelled and repelled equally at the ſame Time by the Force of the Spring, it does not make the Impreſſion paſs into the Hand which ſuſtains it; and the Hand only feels the abſolute Weight of the Liquor, or the Weight of one Pound. But is the Baſe detached ſuddenly from the Sides of the Veſſel? The Force of the Spring protrudes it without any Repulſe. Being impelled after this Manner by a Force of an hundred Pounds, it makes the whole Impreſſion of it felt; and this is the Charm which at once changes a Weight of one Pound into a Weight of an Hundred.

Ariſt. Suppoſe that this Liquor of one Pound, ſuddenly changed into a Weight of an hundred Pounds, happens to freeze upon the moveable Baſe. What will happen?

Eud. The freezing will make one Pound Weight of an hundred Pound Weight; for the Force of the Springs, which proceeds from the univerſal Action of the Parts, will be ſuſpended, ſince all the Parts will be faſtened and linked together after ſuch a Manner by the cold that they cannot flow, or be agitated or ſeparated, or afford any Thing to the Mechaniſm of the Spring. Let Heat ſucceed the Cold: You will quickly find, as before, a Force of an hundred Pounds in a Weight of one Pound.

Ariſt. Can you find upon this Principle, and thoſe which you have eſtabliſhed, the Cauſe why a Stream of Water is ſufficient to raiſe and burſt the Bottom of a Caſk loaded with a conſiderable Weight?

Eud. Yes, without doubt. Fill a great Hogſhead with Water. Pierce the Hogſhead being full and well cloſed. To the Hole which you have made, apply a Pipe of a certain Length, and as narrow as you pleaſe. A Stream of Water poured in through this Pipe, compreſſes all the Water which it encounters in the ſame Column, in Proportion to its Height, by the ſecond Propoſition: The Preſſure of this Column paſſes to the neighbouring Columns; theſe communicate it ſucceſſively to all the other, by the fifth Propoſition. All the Water of the Caſk is extraordinarily compreſſed. Being extraordinarily compreſſed, it makes extraordinary Efforts in order to get at Liberty, like a bended Bow; the Sides of the Caſk ſeconded by the external Air, which weighs much leſs than Water, not being able to ſuſtain thoſe Efforts, the Efforts prevail, and the Caſk burſts.

PROPOSITION VII.

" Liquid Bodies of the ſame Species, which
" have an immediate Communication with one
" another in ſome Part, act preciſely againſt
" one another in the *Ratio* of their Height.
" By their being more or leſs large, their re-
" ciprocal Action is not more or leſs ſtrong.

For thoſe Bodies act againſt one another in Proportion to their being compreſſed, by the Proof of the fifth Propoſition. Now, they are preciſely compreſſed in the *Ratio* of their Height, by the ſixth Propoſition. Therefore they act againſt one another preciſely in the *Ratio* of their Height, and a Stream of Water might elevate the whole Sea. Hence pour Water into communicating Tubes, *Fig.* 23. one of which is an hundred Times larger than the other. The Water places itſelf and remains upon a Level in both, provided the ſmaller one be not a Capillary Pipe or too ſmall. For in a Pipe whoſe Diameter is a third of a Line, the Water aſcends above the Level; becauſe having a larger Surface in Regard of its Maſs, and being better ſupported by the Inequalities, and the almoſt contiguous Sides of a Pipe ſo narrow, it acts leſs in Proportion to its Height againſt the Water of the great Tube, than the Water of the great Tube acts againſt it.

The Water of the capillary Pipe muſt be above the Level, that it may be in *Æquilibrium* with that of the great Tube. But this extraordinary Effect proceeds from the Smallneſs of the Pipe, and not from the capillary Column of the Liquor.

PROPOSITION VIII.

“ Finally, liquid Bodies, which flow, paſſing
“ from a larger Space into a ſtraiter, accelerate
“ their Motion in the Paſſage.

For 1. In that Caſe the lateral Parts, which meet with ſome Impediment in the ſtraitened Sides of the Channel; are more compreſſed by thoſe which follow and inceſſantly overtake them; being more compreſſed they make the greater Impreſſion upon the Parts which flow directly and freely in the narrower Channel; and theſe finding a free Paſſage, make the leſs Reſiſtance to thoſe. 2. In this Situation, more Liquor muſt run in equal Times in a leſs Room, which cannot be done without the Velocity be accelerated. Thus the Water which flows under the Arches of a Bridge, runs more ſwiftly than it did before in a larger Channel. And the Liquor thrown out of a Syringe acquires in its Paſſage a Velocity of ten Degrees, if the Paſſage is ten Times ſtraiter than the internal Part of the Cylinder; for a Piſton ten Times larger than this Paſſage cannot advance an Inch in an Inſtant, but all the Liquor being decuple in Largeneſs, muſt advance an Inch in an Inſtant; all this Liquor thruſt forward by the Piſton cannot advance an Inch in an Inſtant, unleſs an Inch of Liquor decuple in Largeneſs, run out in an Inſtant by a Paſſage ten Times leſs; an Inch of Liquor ten Times larger cannot run out in an Inſtant by a Paſſage ten Times leſs, if the Liquor do not acquire a Velocity of ten Degrees in running out; ſince it is neceſſary that ten Parts, of the Length of an Inch, and as wide as the Paſſage, paſs ſucceſſively in an Inſtant; which cannot be done, unleſs they advance ten Times ſwifter than before: In a Word, every one has only the tenth Part of a diviſible Inſtant, to paſs through whole and intire.

Can you find, *Ariſtus*, in thoſe Truths which I have been ſpeaking of, the phyſical Cauſe of a very ſingular Effect? You ſee this Tube ſtopped at one End, near the other is a moveable Key, which ſhuts and opens it at Pleaſure; ſeveral communicating Tubes cut it at right Angles. I inſert every one of thoſe Tubes into the Orifice of a Hog's Bladder. Over the Bladders I put an horizontal Board, and over the Board a Weight of 1000 Pounds. A Child blows at ſeveral Times into the Pipe in the Middle; the Key being turned about, hinders the Air from iſſuing out, while the Child takes freſh Breath, the Bladders are inflated, and the Weight aſcends. How does the Breath of a Child raiſe a Weight, which the moſt robuſt Man cannot move without a Machine?

Ariſt. A Stream of Water, which deſcends by a communicating Tube upon the Liquor which fills a Caſk perpendicular to the Horizon, raiſes the ſuperior End of the Caſk, even when it is loaded with a conſiderable Weight; becauſe the Exceſs of Compreſſion, and conſequently of the Spring, which the Stream of Water gives the inferior Column, is by it communicated to all the Columns, and the Exceſs of the Compreſſion acts univerſally. After the ſame Manner the blowing of a Child lifts up an extraordinary Weight, becauſe it gives the Air, which it directly encounters in the middle Pipe, an Exceſs of Compreſſion and Elaſticity, which is communicated univerſally, ly; as in Liquors, and which conſequently paſſes into all the Parts of the Air in the Bladders. In Proportion as the Child blows, the internal Air receives from a more agitated Air, which comes in, a new Exceſs of Preſſure and Elaſticity; and this Exceſs ſucceſſive and united under the Weight by the Bladders, raiſes up the Weight more and more, and that ſo much the more effectually, as the Exceſs of Maſs, which is found in the Weight, is leſs than the Exceſs of Velocity which is in the Child's blowing. Thus the blowing of a Child produces a prodigious Effect.

Eud. After this, *Ariſtus*, we may divert our ſelves a little with the *Æquilibrium* of Liquors.

CONVERSATION XXI.

Upon Hydroſtatics, or the Æquilibrium *of Liquors* ‡.

Eud. DO you explain the ſecret and reciprocal Action of liquid Bodies, and I will endeavour to explain that of liquid and ſolid Bodies. We ſhall have the Pleaſure of ſeeing them counterbalance one another, overcome, yield, aſcend, deſcend, and reſt, being always more conſtant and faithful in obſerving certain Rules, than if they were endued with Reaſon.

Ariſt. Whenever liquid Bodies touch one another, the Compreſſion which proceeds from the Gravity, and the Motions of Elaſticity and Liquidity make them act univerſally againſt one another; and as they are not free, they act with all their Force in Order to ſurmount every Impediment. Are their Forces equal? None of them aſcends, none of them deſcends, none of them prevails, none of them yields, by Reaſon of the Equality of oppoſite Forces. Are they unequal? The heavieſt deſcends, becauſe being protruded more ſtrongly toward the Center of heavy Bodies, it ought to approach it. The leſs weighty aſcends; becauſe the one cannot deſcend, unleſs the other aſcend in Order to make Room for it, and the leſs Force ought to yield to the greater.

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‡ See the Notes on the foregoing CONVERSAT.

Hence, 1. All the perpendicular Parts and Columns of liquid Bodies endeavour, as much as they can, to elevate one another, ſince they all act againſt one another, every Way, and with all their Force.

2. The leſs weighty Parts and Columns ought to aſcend, having leſs Force to reſiſt the Effort of the more weighty, which endeavour to elevate them. Accordingly they aſcend. Sink into Water the End of a Syringe, and draw the Piſton: The Water follows it, being thruſt by the next Columns that are heavier and ſtronger.

3. You would ſay that Liquors of the ſame Species affect to be placed on a Level: Why? Becauſe if any Part is above the Level, that below it being more compreſſed, and conſequently heavier than the lateral Parts, which are not charged with the ſame Weight, deſcends and makes them aſcend, till they are all in an *Æquilibrium* upon the Level, or in a Circle whereof all the Points are equally diſtant from the Center of heavy Bodies.

4. Liquid Bodies of a different Species, and of different Gravity, are not placed upon a Level; becauſe the heavier ought to deſcend,

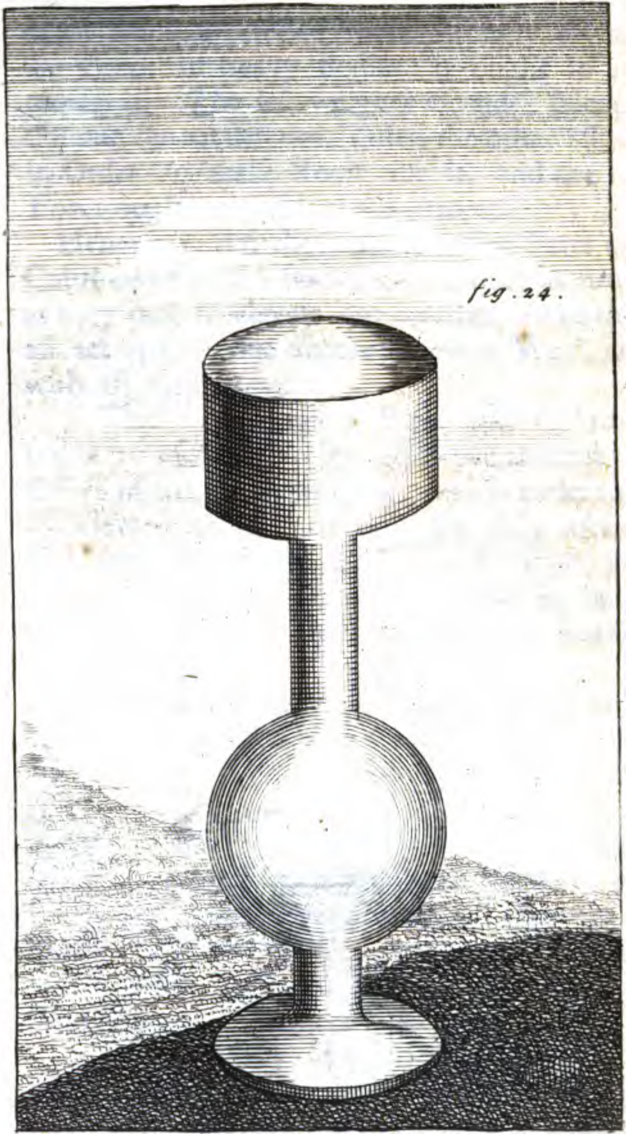

fig. 24.

elevate and ſuſtain the other. In Water we ſee Bubbles of Air aſcend rapidly till they reach the Surface, the Reaſon is, becauſe Air is much lighter than Water.

Eud. I take, *Fig.* 24. a ſmall Glaſs-Tube, [Paſſe-vin] which ſuſtains a ſort of Cup, and whoſe Baſe is a ſort of Phial of the ſame Matter; I fill the Phial with red Wine. Then I fill the Cup and Tube with Water. You ſee a Stream, a Column of Wine, aſcend calmly from the Phial into the Cup, while a Column of Water deſcends from the Cup into the Phial through the Tube, until the Wine have taken the Place of the Water, and the Water the Place of the Wine. What is it that determines thoſe Liquors to change Place?

Ariſt. The Inequality of the Weight. The Column of Water is heavier, deſcends and elevates the Column of Wine.

Eud. But why is no Mixture made of thoſe two Liquors in the Tube, as happens when I pour Water immediately upon Wine, or Wine upon Water in a Glaſs?

Ariſt. The Water being turned over at firſt into the Cup, and deſcending upon the Wine through a very narrow Tube, deſcends gently, or elſe covering all the ſmall Surface of the Wine almoſt at the ſame Time, it does not find Acceſs into it, till after having loſt much of its Velocity acquired in its Fall. Hence the two Columns of Wine and Water are quiet beſide one another: In this Situation their Parts, whoſe Agitation is very moderate, are much compreſſed, and have not Motion or Force enough to divide one another, to penetrate, to inſinuate themſelves, and to be intangled in one another's Interſtices; and, in a Word, to be mixed with one another. But the Water which I pour upon Wine, or the Wine which I pour upon Water in a Glaſs, acquires in its Fall, being more free and upon a larger Surface, Motion and Force enough, to invade the Particles of Wine, diſturb their *Æquilibrium*, diffuſe itſelf into their Pores, or to receive them into its own, and be intangled with them without being able to diſengage itſelf, after having loſt much of its Force by Friction. And this is what cauſes the Mixture of Wine and Water in a Glaſs, although Water be more weighty.

In a Word, pour Water immediately into the Glaſs, put a light Slice of Bread upon the Water, and then let Wine flow gently upon the Bread: The Wine, which would be mixed, if poured on as they commonly pour it, diffuſes itſelf upon the Water, without deſcending or being mixed. Why? Becauſe in falling upon the Bread, and being filtred through its Pores, it loſes much of the Force which it had acquired in its Fall; and, having at laſt no more than the Force of Gravity to mix and deſcend, it cannot make itſelf in the Water, being heavier, free Paſſages in Order to mix with it, and deceive the Eyes rather than the Taſte, by communicating its Colour to the Water. Here are ſome Traces of the mutual Action of liquid Bodies. What Rules do ſolid Bodies obſerve, which meaſure their Force immediately with liquid Bodies?

Eud. The Bulks being ſuppoſed equal, a ſolid Body weighs more, leſs, or equally ‖? *Rule* 1. Does it weigh more? It ſinks wholly. *Rule* 2. Does it weigh leſs? It ſwims uppermoſt. *Rule* 3. Does it weigh equally? It ſwims and remains ſuſpended in the Liquid.

1. Does it weigh more? It deſcends and ſinks wholly. For being heavier, it ought to approach nearer to the Center of heavy Bodies. It cannot do that without elevating above it the lighter Bulk; which by its Weight and Liquidity ought to be diffuſed over it: Therefore it deſcends and ſinks entirely.

How ſhould it not ſink after that Manner? Being more weighty, it is ſtronger; being ſtronger, it ought to elevate the Bulk that is lighter, and conſequently weaker. A ſuperior Force, whenever it is neceſſary, is always victorious: Therefore, &c.

‖ In all homogeneous and equal Bodies, the Denſities are as the Weights; in unequal Bodies of the ſame Weight, the Denſities are inverſely as the Bulks; if therefore both the Weights and the Bulks differ, the *Ratio* of the Denſities is compounded of the direct *Ratio* of the Weights, and the inverſe *Ratio* of the Bulks; and therefore *dividing the Weights by the Bulks, you have the Denſities*, that is, you will have Numbers that are to each other as thoſe Denſities.

The Weight of all Bodies may be compared by Means of the Balance; the Bulks are found by *immerging Bodies in the ſame Liquid; for the Weights which they loſe, are as their Bulks.* *Vide* Graveſande's Elem. Vol. I. p. 159, *&c.*

In a Word, being more weighty it preſſes the inferior Parts the more. Thoſe Parts being more preſſed, preſs the lateral Parts more. Theſe being more compreſſed aſcend, ſince they endeavour to extend themſelves every Way, and find leſs Reſiſtance above the ſolid Body, always ready to yield its Place to them. In aſcending they have their Place filled up again by the Parts which the ſolid Body puſhes immediately; theſe do not leave their Place but only to give it to the ſolid Body. Thus a ſolid Body that weighs more, wholly ſinks and deſcends.

2. Does it weigh leſs? It floats above. Being leſs weighty, and by that Means leſs ſtrong, it ought leſs to approach the Center of heavy Bodies, and to be elevated by giving Place to the heavier Bulk, which is conſequently the ſtronger; the leſs Force always yields: Therefore it floats atop. Nevertheleſs in floating above it does not ceaſe ſinking to a certain Point, ſince being heavier than the Air, it preſſes the Surface of the Liquor more.

3. Does it weigh equally? It floats and remains ſuſpended in the liquid Body. Being equally heavy, and thereby equally ſtrong; whenever it is placed in the Boſom of the Liquid, it can neither deſcend nor aſcend, ſince it can neither overcome nor yield. Equal Powers

Vol. 1. p. 295.

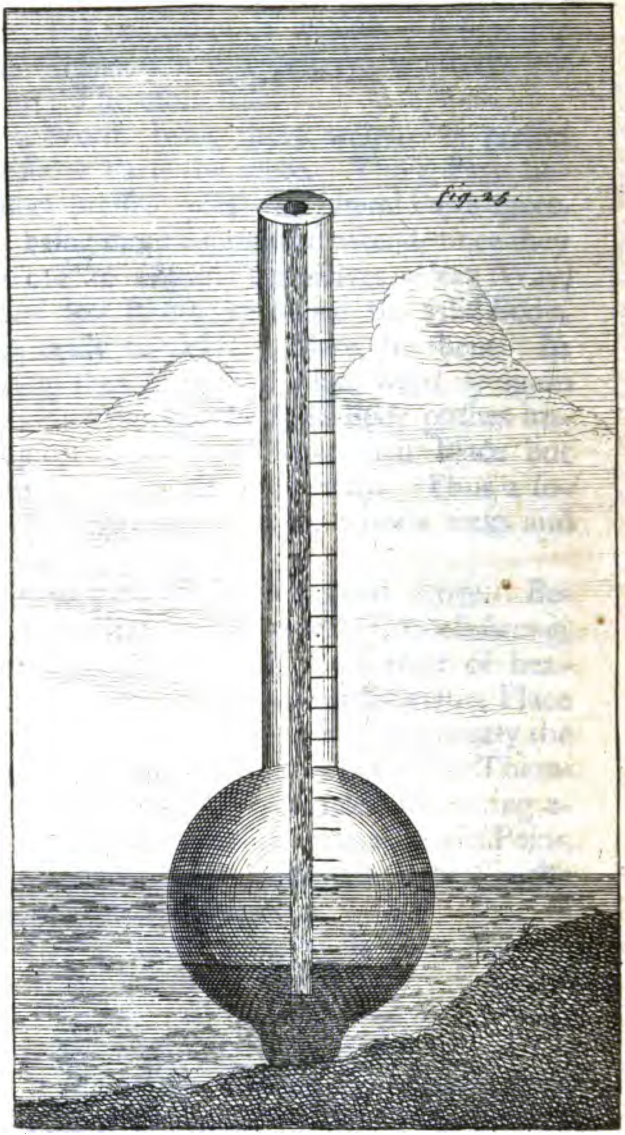

fig. 25.

ers are neither vanquiſhed, nor victorious; therefore, &c.

Hence, 1. A ſolid Body which you ſuſtain, weighs leſs with Reſpect to you, or loſes of its relative Weight in Liquors, proportionally as they are more or leſs weighty.

They ſuſtain it in Proportion to their Weight, and you have not that to ſuſtain which they ſuſtain. A ſolid Body which you ſuſtain in Water, does it weigh ten Pounds in the Air? You only employ a Force of eight Pounds in order to ſupport it, if an equal Bulk of Water weigh two Pounds; becauſe it ſupports the Weight of two Pounds. Let us ſuppoſe two Pounds in *Æquilibrio* in a Balance. Let the Balance deſcend: If one of the two Pounds deſcend into the Water, it loſes immediately of its Weight, with Reſpect to the other, in Proportion to the Weight of the Water: There is no more *Æquilibrium*, and the other outweighs. In ſhort, Lead weighs leſs by a tenth Part in the *Seine.*

2. A ſolid Body, which ſwims, ſinks proportionally as there is in the Liquor a greater or leſs Exceſs of Gravity. The Liquor-Balance or Areometer, *Fig.* 25. (it is a ſort of ſmall Glaſs Phial with a long Neck, ſealed and cloſed hermetically; full of Air, and having a little Mercury in the Bottom). The Liquor-Balance, I ſay, is ſunk more or leſs in different Liquors; more in Wine than in Water; and more in freſh Water, than in Salt Water.

Why? 1. The Liquor-Balance ſwims above; becauſe it cannot deſcend and ſink wholly, unleſs the Bulk compounded of Air, Mercury and Glaſs be wholly ſunk; and this Bulk cannot be wholly ſunk. The Mercury and Glaſs, each in particular, are heavier than the Liquor; but the whole Bulk, by Reaſon of the Exceſs of Levity which is in the Air that it contains, weighs leſs than an equal Bulk of Liquor. 2. The Liquor-Balance ſinks more in Wine than in freſh Water, and in freſh Water than in Salt. You ſee the Reaſon of it; becauſe Wine weighs leſs than freſh Water, and freſh Water leſs than Salt Water. The Salts, being more ſolid than pure Water, give a greater Gravity to the Salt Water.

Ariſt. Your Liquor-Balance makes me comprehend why ſuch a Veſſel, which ſails ſafely upon the Sea from one End of the World to the other, would ſink gently to the Bottom in the freſh Waters of a River or Lake. The Reaſon is, becauſe the Salt Water of the Sea being much heavier than the freſh Waters of a Lake or River, can ſupport a much greater Weight.

Eud. Nevertheleſs one may make the moſt ſolid Bodies, Stones, Braſs, and Gold itſelf, to float upon the freſh Water of a River. Make a Bridge of Stones as long as you pleaſe; let this Bridge have for Pillars only moveable Boats, which, without being able to move forward or backward, may deſcend or aſcend, in Proportion

portion as the Water aſcends or deſcends, like the Bridge of *Rohan*; this Bridge of Stones, being loaded with Animals, Men, and Coaches, will not ceaſe to float above; becauſe the Bulk of Stones, Men, Coaches, Boats, and Air contained in the Boats, will be more light, by Reaſon of the Levity of the Air, than an equal Bulk of Water. By the ſame Reaſon, cover the Breadth of a River with Boats of Braſs, or Gold, if you will; a whole Army may paſs over, without the Braſs or Gold ceaſing to ſwim.

Ariſt. Your Opinion, *Eudoxus*, appears natural; but one Thing which occurs to my Mind, has a Tendency to deſtroy it. A Needle of Steel, placed gently and horizontally upon the Surface of Water, ſwims. I think it ought to ſink intirely. It has neither the Form of a Boat, nor the Levity of the Air, to ſuſtain it; and Steel is heavier than Water.

Eud. The Levity of the Air, and the Form of a Boat, with the Viſcoſity of the Surface of the Water, produce this Effect ſtill. How is it produced? The Air is more eaſily attached to the Needle than the Water is, for the Needle is not eaſily wetted; the Water runs over it, without finding any Hold on it. This being granted; upon the viſcous Surface of the water, whoſe Viſcoſity renders the Parts more difficult to ſeparate, the Weight of the Needle with the Air which ſurrounds it, lays hold on it, and continually envelops it, makes a ſort of Cavity *, in which the Needle is contained as in a ſmall Boat. The Bulk composed of the ſmall viſcous Boat, Needle and Air, is lighter than an equal Bulk of Water; though the Needle alone be heavier than an equal Bulk of this Liquor. The Needle ought therefore to ſwim much after the ſame Manner as a Boat of Braſs, or as a Beam ſwims, becauſe of the Air which it contains in its Pores.

Ariſt. In ſhort, wet the Needle firſt: Thereby you detach from it a Quantity of Particles of Air, and fill up many inſenſible Pores of its Surface with Particles of Water; the Exceſs of Gravity ſinks it, and makes it diſappear to the Eye.

Eud. But the Wood, which at firſt ſwims above as the Needle of Steel, is at laſt wholly ſunk. Whence does this Viciſſitude of Gravity and Levity proceed?

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* This is owing to *Repulſion*, of which we have farther Inſtances between Water and Oil, and generally between Water and all Unctuous Bodies; between *Mercury* and Iron; as alſo between the Particles of any Duſt.

If any greaſed Body, lighter than Water, is laid upon the Surface of Water, or Piece of Iron upon *Mercury*, the Surface of the Fluid will be depreſſed about the Bodies laid upon it. And where *Attraction* obtains, the Surface of the Liquor is higher about the floating Bodies, and does not run to a Level by its Gravity; but here where the repellent Force exerts its Action, Liquors, notwithſtanding their Gravity, do not run down to fill up the Cavities which are made round the floating Bodies. *See* CONVERSAT. IX and XIV. Vol. I. and *Graveſande's Elem.* Vol. I. p. 15.

Ariſt. With the Air which it contains at firſt it makes a lighter Bulk, and it ſwims. With the Water which penetrates it, and at length takes the Place of the Air which is forced to iſſue out, it makes an heavier Bulk, and ſinks intirely. You are going to make me comprehend, no doubt, a Thing difficult to be conceived. Throw into cold Water a Ball of Wax, and it ſwims. Warm the Water, and the Ball ſinks; increaſe the Heat, and the Ball aſcends again.

Eud. 1. The Ball of Wax floats at firſt, becauſe it weighs leſs than cold Water. 2. Afterward the Ball ſinks, becauſe it weighs more than an equal Bulk of Water rarefied by the Heat. 3. The Ball aſcends again at laſt, becauſe being at laſt rarefied itſelf by the Exceſs of Heat, which penetrates and dilates the Air that it contains, it becomes lighter than an equal Bulk of Water. You may find the Explication of a contrary Effect from the ſame Principles. A Carcaſs deſcends immediately in Water; after that it reaſcends, and then ſinks again as of itſelf.

Ariſt. 1. The Carcaſs deſcends at firſt in the Water, becauſe it is heavier. 2. It reaſcends, becauſe the Fibres being relaxed for Want of Nouriſhment, or by the Action of the inſenſible Parts of the Water, the internal Air is ſet at Liberty, is extended, and enlarges the Bulk of the Body; and the Body having more Bulk, in Regard of its Maſs, becomes at laſt lighter than an equal Volume of Water. 3. It ſinks again, becauſe the ſolid Parts from which the Air is gone forth, approach one another, and make the Body heavier and more compact.

Eud. But ſince there is more Weight in an human Body than in an equal Bulk of Water, how do thoſe ſwim above who bathe themſelves? How do they paſs over Rivers by ſwimming?

Ariſt. 1. Being extended their whole Length upon the Surface of the Water, they cannot ſink unleſs an equal Volume of Water open and give Place at once. But the Water opens and gives Way with ſo much the more Difficulty as a longer, larger and deeper Extenſion ought to open and give Place at once: For it muſt open and give Way with ſo much the more Celerity; and the Reſiſtance of a Body anſwers to the Velocity neceſſary to move it. 2. The Air which they reſpire, being much lighter than Water, diminiſhes their relative Weight. 3. They compreſs the Water not only by their abſolute Gravity, but likewiſe by the Motion of their Bodies; and the more they compreſs the Water, the greater Effort it makes to ſuſtain them. In fine, by the Motion of the Arms and Feet they raiſe up the lateral Water; the adjacent Columns of Water are thereby longer; being longer they weigh more, ſince they all weigh in Proportion to their Height. This, I think according to your Principles, is the Reaſon why we keep on the Surface when we bathe: Nevertheleſs I would not attempt to ſwim over the *Seine* upon the Force of this Reaſoning.

Eud. Motion hinders from ſinking, and makes the Diver aſcend again from the Bottom of the Sea upon the Surface of the Water. Is he in an *Æquilibrium* at the Bottom of the Sea? Let him ſtrike the Earth with his Foot, endeavouring to ſpring up to the Top. The perpendicular Motion which he acquires in this Effort diminiſhes his relative Gravity, and being ſeconded by the lateral Column, he raiſes himſelf above the Surface of the Water. All Motions diminiſh relative Gravity, excepting the direct Motion toward the Center of heavy Bodies: Hence you ſee Dregs and Sugar, when agitated, aſcend in Liquor, and Duſt riſe up in the Air and darken the Sky.

Ariſt. You would make one believe that if a Philoſopher, who had no Skill in ſwimming, and whom ſome Miſchance ſhould have precipitated into the Bottom of a River, had Preſence of Mind enough to ſtrike the Earth with his Foot, and ſpring up to the Surface, he might ſee the Bank; then being again precipitated by his own Weight, he might go along upon the Ground toward the Bank. Should he want to breathe, he might return and breathe above the Surface of the Water. When his Weight had again dragged him down to the Bottom, he might creep along as before, at laſt gain the Bank of the River, and eſcape

Danger by the Favour of his cool Blood and his Philoſophy.

Eud. This he might do without being a great Philoſopher. Some Time ago I ſaw a Man, who without knowing the *Æquilibrium* of Liquors, finding himſelf unhappily plunged into the Middle of a large and deep River, reached the Bank by creeping along under Water; while five or ſix Perſons, whom a Shallop that was overſet had thrown into the Water, were drowned in the ſame Place.

Ariſt. Water which ſuffocates us gives Life to Fiſh that are deſtined to yield us Nouriſhment. But how do Fiſh ſwim? How do they remain ſuſpended and immovable? How do they aſcend and deſcend with ſo much Liberty in the Water?

Eud. Fiſh have in their Bodies a ſort of Bladder full of Air. In contracting it they contract the Body, and have more relative Gravity. By that Means at one Time they weigh as much as an equal Bulk of Water, and are immovable, or ſwim in the Water without deſcending or aſcending: At other Times they weigh more and deſcend: Again, they weigh leſs and aſcend. The Efforts which they make in turning and winding, by beating the Water as a Point of Suſpenſion with the Tail, ſeconds their Viciſſitudes of Gravity and Levity. I have made the Fiſh ſwim; do you make the Birds fly.

Ariſt. It is eaſie to do that upon your Principles, after what has been ſaid. Birds of themſelves have more Gravity than an equal Volume of Air; the Partridge being mortally wounded by the Fowler's Shot, falls whenever ſhe can fly no more. But this Exceſs of Gravity is compenſated ſeveral Ways.

1. Birds which fly, dilate their Breaſt, extend their Wings, acquire a larger Bulk; and by that Means their relative Gravity is diminiſhed.

2. Having a larger Bulk they divide the inferior Air with more Difficulty, becauſe they muſt communicate to it a greater Velocity, and drive it farther in the ſame Time to divide it; and becauſe it reſiſts ſo much the more, the greater Velocity it requires in Order to its yielding.

3. The more they rapidly beat the inferior Air with their Wings, the greater Reſiſtance they find from it; for it requires a greater Velocity to yield to the reiterated Strokes. The Air being beat with ſo briſk and quick a Stroke, that it has not Time to retreat, becomes a fixed Point for the Flight of Birds. By beating the Air with their Wings, as the Fiſh do the Water with the Tail, or the Diver the Earth with his Foot; they give themſelves a Motion either to aſcend or go forward. The inferior Air being compreſſed, ſeconds this Motion, as Water being puſhed by the Oar behind the Shallop, ſeconds the Effort of the Rower; and as long as this Impreſſion laſts,

you ſee Birds fly and hover in the Air, remain ſuſpended, aſcend and deſcend, much after the ſame Manner as Fiſh do in the Water.

Eud. When one underſtands the Flight of Birds, one may eaſily comprehend the floating Iſlands.

Ariſt. Theſe are Tiſſues of Roots and Herbs mixed with a little Fuller's Earth; they are Maſſes compoſed of Fuller's Earth and Roots lighter than Water, which with the Earth and Air contained in them, form a Bulk lighter than an equal one of Water: This Exceſs of Lightneſs makes them float; and theſe are your floating Iſlands.

Eud. Before we finiſh this Converſation, let me have the Pleaſure of perplexing you. Leſs Water is required to ſuſtain a floating Iſland, or a Veſſel in a narrow Place, than in one that is large and ſpacious.

Ariſt. In a very large and ſpacious Place the Water is ſpread more abroad, and riſes to a leſs Height; but in a more contracted Place the Water is ſpread leſs abroad, and riſes higher. Now the Water weighs, counterbalances and ſuſtains the floating Iſland or Veſſel preciſely in Proportion to its Height (by your ſeventh Propoſition of our laſt Converſation). Hence the narrower a Haven is, the leſs Depth is required in the Water.

Eud. But to conclude, what Method would you take to deſcend into the Bottom of the Sea

in

Vol. 1.

p. 305.

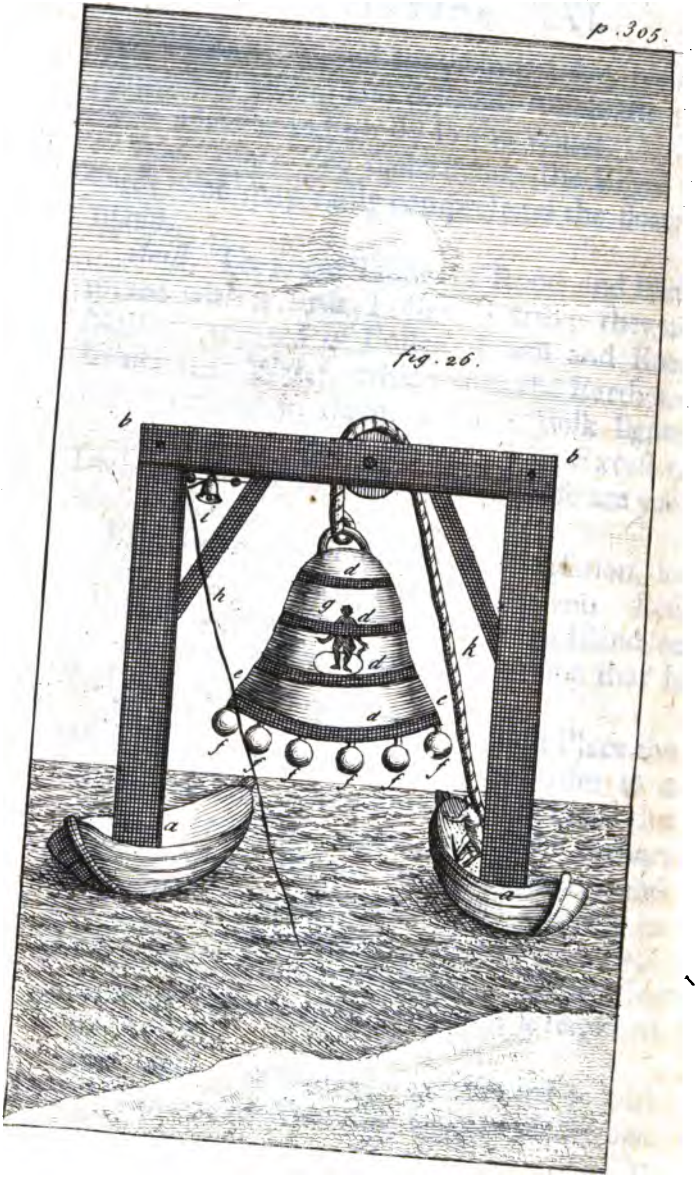

fig. 26.

6

in a great Volume of Air, and to carry Fire with you, without its being extinguiſhed?

Ariſt. I would place my ſelf upon a Plank in a Bell which ſhould be made to deſcend perpendicularly into the Water, with the Mouth downward. The Bell, by Reaſon of its Figure, having the Parts ſupported by one another, would ſuſtain the Weight of the Water; the internal Air, which would find no Vent to iſſue out at, would hinder the Water from entering very far by the Orifice, to wet me, and to extinguiſh the Fire.

Eud. It is a ſingular Contrivance, which has been luckily made Uſe of to bring up from the Sea ſome Millions of Pieces of Eight after a Shipwreck, *Fig.* 26. They ſuſpended upon the Middle of a Croſs-Tree *(bb)*, which was ſupported upon two large Boats *(aa)*, a Bell of Wood, from 13 to 14 Foot high, and nine Foot wide. It was encompaſſed with Iron Hoops *(dddd)*; the Hoop at the Brim *(ee)* had ſeveral Iron Rings, to which were faſtened as many Bullets *(ffffff)* to render the Bulk weightier than an equal Volume of Water, notwithſtanding the Levity of the internal Air. A Man *(g)* was ſeated in the middle of the Bell. He held a ſmall Cord *(h)* to ring a little Bell, when he had deſcended low enough, or was willing to aſcend again. The little Bell *(i)* was faſtened to the Croſs-Tree. The Man being deſcended, gathered up the Piaſters, and went from Time to Time to breathe under the Bell. When the Air was heated too much, he rung the little Bell. Then by Means of a Cable (*k*), they drew him up again with the Bell and Piaſters.

This Fact was learned from one who had been an Eye-Witneſs of it [c].

You at firſt, *Ariſtus*, laid down what regards liquid Bodies in general; and when one comprehends the *Æquilibrium* of Liquors, one may eaſily diſcover the Properties of the Air. We have already diſcovered its Elaſticity; let us endeavour to diſcover its Gravity; let us meditate upon theſe two Properties, each apart; then uniting our Lights we ſhall find an almoſt univerſal Agent in the Air, which is ſo little minded; and ſhall obſerve in its Gravity and Elaſticity the Principles of a Thouſand Effects, which are looked upon as ſo many Miracles in Nature.

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[c] Journ. des Scav. 1678. p. 137. 4 *Avril.*

CONVERSATION XXII.

Upon the Gravity of the Air, and its Effects.

Ariſt. YOU will have it then, *Eudoxus*, that the Air weighs, however imperceptible and fine it be; and that we have the Weight of the Atmoſphere to ſuſtain, without our perceiving it*?

Eud. A Body, which affords ſome Hold to the Strokes of the ſubtile Matter which is the Cauſe of Gravity in Bodies, is ponderous. But the Air affords ſome Hold to the Strokes of the ſubtile Matter, ſince it is groſſer, as we have obſerved in the Air Pump*: Therefore the Air ponderates.

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* The *Air* is corporeal, heavy, its Parts yield to any Force impreſſed, and are very eaſily moved amongſt one another; it preſſes in Proportion to its Height, and the Preſſure every way is equal: It is plain therefore that it ought to be *reckoned amongſt Fluids*.

Def. I. *All the Air which the Earth is encompaſſed with, conſidered together, is called the* Atmoſphere of the Earth, *or ſimply*, the Atmoſphere.

Def. II. *The Height of the Air above the Surface of the Earth is called the Height* of the Atmoſphere.

That the Air is a Body appears from its excluding all other Bodies from the Place where it is.

That it yields to any Impreſſion, and has its Parts eaſily moved, is not doubted by any one.

That it is heavy is proved by its preſſing upon the Surfaces of other Fluids, and ſuſtaining them in Tubes.

In ſhort, a Body which with another Body makes an heavier Volume, ponderates. Now the Air is a Body, which with another Body makes an heavier Volume; a Veſſel full of Air has more Gravity than when it is empty of Air. *M. Homberg* pumped out the Air from a ſort of Glaſs-Ball, whoſe Diameter was 13 Inches; and the Ball was lighter by an Ounce than before[d]. Another Time, after having pumped out the Air from a Ball of 20 Inches Diameter, he found it at leaſt two Ounces lighter[e]. Therefore the Air is weighty.

Ariſtotle was ſenſible of this Truth, but made little Uſe of it, and it ſeemed to be eclipſed till the Time of *Toricellius*, who diſcovered and rendered it intelligible to Father *Mercenne*, a famous Monk. Father *Mercenne* imparted it to *M. Paſchal. Guerick*, the famous Conſul of *Magdebourg*, and *Boyle*, a learned *Engliſhman*, have demonſtrated it by very curious Experiments.

Ariſt. It ſeems at firſt Sight, that if the Air ponderates, we ought to be overwhelmed under the Weight of the Atmoſphere. But we ſee there is nothing to be feared on that Side. A Weight is not felt but when it cauſes ſome

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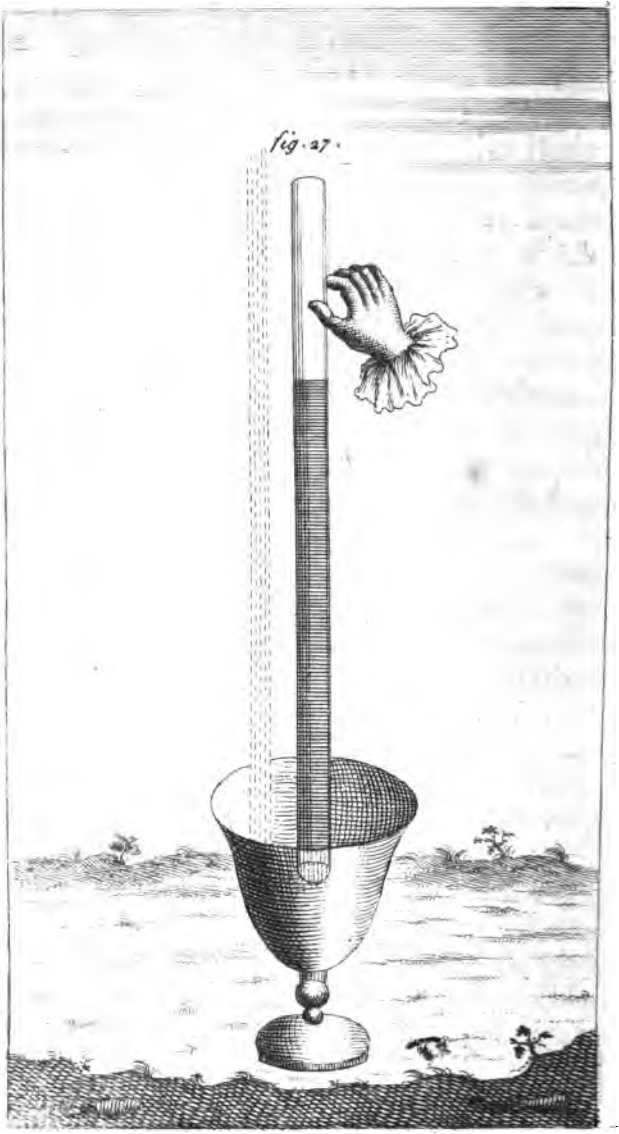
* CONVERSAT. III.

[d] Hiſt. de l'Acad. 1687. p. 260.

[e] Hiſt. de l'Acad. 1696. p. 403.

Change

fig. 27.



Change in the Organs of the Senſes, as you have made me obſerve: The Weight of the Air cauſes no ſuch Thing, ſince the Air encompaſſes the whole Body, and preſſes it equally on all Sides, both within and without.

Eud. Are you willing, *Ariſtus*, that I ſhould preſent you with divers Facts which particularly reſpect the Gravity of the Air? You will explain them with your uſual Penetration, and your Explication will give ſome Light to the Truth.

I pour Mercury into a Veſſel; then I fill with Mercury this Glaſs-Tube of 36 Inches, cloſed up at one End with a Hog's Bladder. I ſtop the other End with my Finger, and plunge it into the Mercury in the Veſſel; I remove my Finger: The Mercury of the Tube deſcends, and after ſome Ballancings, ſtops at 27 or 28 Inches, or thereabouts *(a)*, *Fig.* 27.

Ariſt. I ſee at once the Reaſon of it upon your Principles. The Mercury deſcends at firſt, being impelled by the Gravity. While it deſcends, the accelerated Motion of its Fall makes it prevail over the Column of external Air, which counterballances it; it is carried below the Point of *Æquilibrium.* But the Column of Air being compreſſed, makes its ſpring to play; and prevailing in its Turn, it carries it back above the Point of *Æquilibrium.* Theſe alternate Victories are repeated till the Exceſs of Force is loſt: Hence the Ballancings or Vibrations, which precede the *Æquilibrium.*

Is the Exceſs of Force loſt both on the one Side and the other? The Mercury is ſtopt, becauſe it is in a perfect *Æquilibrium* with the Column of Air, which counterballances it; and as the Air ought to be ſometimes more, ſometimes leſs weighty, in Proportion as it is more or leſs charged with Vapours, or more or leſs compreſſed by the Wind, the Point of *Æquilibrium* is ſometimes higher, ſometimes lower. Hence Mercury, always obedient to the Laws of *Æquilibrium*, reſts without any capricious Humour, ſometimes at 27, ſometimes at 28 Inches, or thereabouts.

Eud. Make the Experiment in a lower Place, the Mercury deſcends leſs. Make it in an higher Place, the Mercury deſcends more. *M. du Perrier* made it near *Clermont* in *Auvergne*, at the Deſire of *M. Paſchal*. At the Foot of *Pierdome*[f] the Mercury deſcended to 26 Inches three Lines and an half. Upon the Brow of the Hill, 150 Fathoms higher, to 25 Inches, toward the Top, 500 Fathoms higher, to 23 Inches two Lines[g].

Ariſt. The lower the Place is, the higher is the Column of Air which ſuſtains the Mercury; the higher it is, it ponderates the more, ſince Liquids ponderate, as you have made it appear[h], in Proportion to their Height; the more the Column of Air ponderates, the more it ſuſtains the Mercury; the more it ſuſtains it, the leſs it ought to deſcend, and the leſs it does deſcend. By a contrary Reaſon, the more elevated a Place is, the ſhorter is the Column of Air; the ſhorter it is, the leſs it ponderates; the leſs it ponderates, the leſs it ſupports the Mercury; the leſs it ſupports the Mercury, the more it ought to deſcend, and the more it does deſcend.

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[f] A Mountain near that Town.

[g] Mariote de la Nature de l'air, p. 196.

[h] CONVERS. XX.

Eud. But in my Cloſet the Column of Air is ſhorter, by Reaſon of the Cieling, than thoſe of the Palace of the *Sorbonne*, or the *Tuilleries.* Is the Mercury lower upon that Account? You ſee it almoſt at 28 Inches.

Ariſt. I have not forgot what you demonſtrated [i], that in Liquids the Action of Gravity is diffuſed every Way. In a Veſſel made in the Form of a Cane, a lateral Column, altho' it be ſhorter than that of the Middle, does not ponderate leſs upon the Bottom; becauſe thoſe of the Middle preſs it as much, as they are preſſed themſelves immediately by the Cauſe of Gravity. After the ſame Manner in your Cloſet, the Column of Air, altho' it be ſhorter than thoſe without, ponderates no leſs upon the Mercury of the Veſſel; becauſe theſe preſs it as much as they are immediately preſſed themſelves by the Cauſe of Gravity. Now, when the ſame Force externally preſſes the Mercury in the Veſſel, that of the Tube ought to remain in the ſame Elevation, ſince it cannot deſcend without raiſing up the Mercury in the Veſſel fixed by the ſame Force.

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[i] CONVERS. XX.

Eud. I ſuppoſe that the Air of my Cloſet has no Communication with the Air without. Ought the Mercury to deſcend?

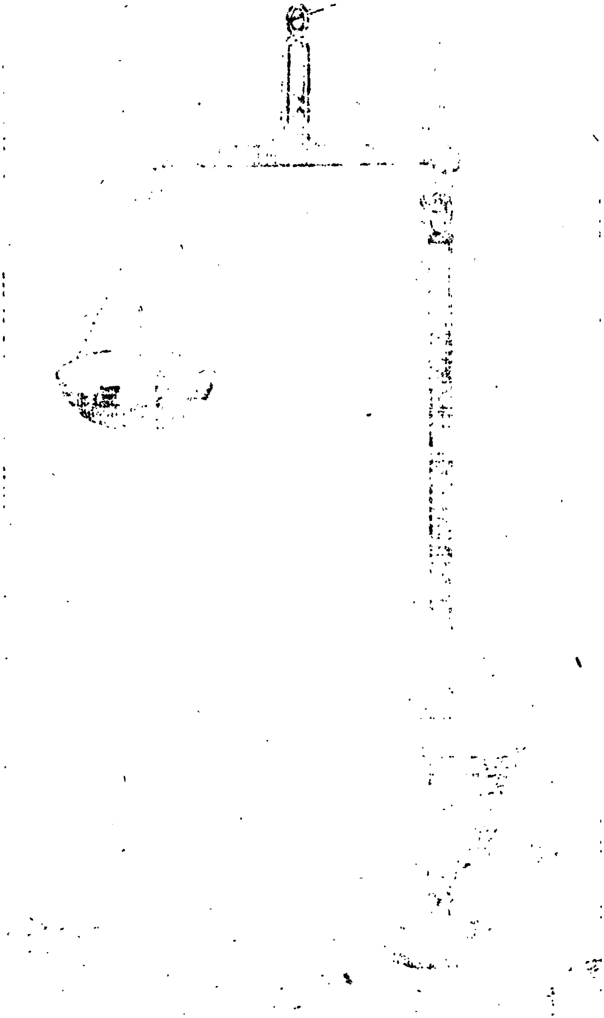
Ariſt. The Mercury of the Tube cannot deſcend without elevating that of the Veſſel; it cannot elevate it without compreſſing the Air of your Cloſet: It cannot compreſs it without ponderating more than the Air without; ſince the Air of your Cloſet retains the Preſſure which it received from the Weight of the Atmoſphere. But the Mercury in the Tube cannot ponderate more than the Air without; they are in *Æquilibrium*: Therefore the Mercury ought not to deſcend

Eud. But if the ſmall Column of Air contained in my Cloſet, ought to ſupport this Mercury; why does My Hand, which holds the Tube, feel the Weight of the Mercury?

Ariſt. The Hand does not feel the Weight of the Mercury.

Eud. It feels an equal, or almoſt equal Weight.

Ariſt. This equal, or almoſt equal Weight is the Weight of the Column which deſcends upon the Tube perpendicularly, and which being no longer ſupported by the adjacent Column, employed in ſuſtaining the Mercury of the Tube itſelf, ponderates upon the Tube with all its Force, and conſequently makes the Hand,



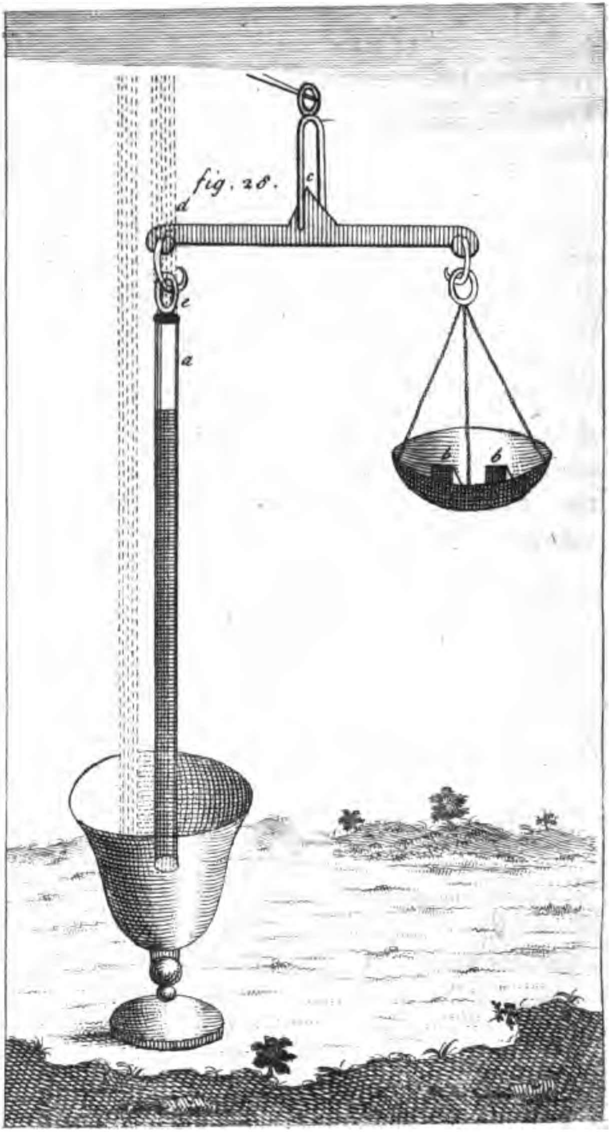


fig. 28.

Hand, which ſuſtains it, feel a Weight equal to the Weight of the internal Quickſilver, ſince it ponderates as much as the neighbouring Column, which is in *Æquilibrio* with the Mercury.

Eud. The Mercury, according to the Obſervation of *M. Amontons*, remains ſometimes unequally ſuſpended in equal Tubes; in Tubes of different Glaſs, and much lower in an Iron Tube[k].

Ariſt. The Inequality of the Pores muſt give Acceſs to ſome Matter more or leſs ſubtile, and unequally ponderous into the Tubes.

Eud. However that be, without having any other Intereſt in View but that of Truth itſelf, let us go about to weigh the Air. Let us weigh the Column which deſcends upon this Tube, *Fig.* 28. I take off one of the Scales of the Balance. Upon the Beam, from which I have looſed it, I ſuſpend the Tube *(a)*, which always contains the ſame Quantity of Mercury. In the other Scale, whoſe Weight equals that of the Tube alone, I put the Weight *(b)* of one Pound. That is the Weight of the Mercury contained in the Tube. I ſuſtain the Balance by the Middle *(c)*. Every Thing remains in a perfect *Æquilibrium*; the Weight of one Pound does not elevate the Tube, which can be retained only by the Weight of the Column of Air *(d)*, which deſcends upon the upper End of the Tube. How much does it weigh?

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[k] Mem. de l'Acad. 1705. Trev. 1712. p. 1408.

Ariſt. It weighs one Pound. For it weighs as much, as the Column which falls upon the Mercury of the Veſſel: There is no other Difference but the Height of the Tube. Now the Column, which falls upon the Mercury of the Veſſel, weighs one Pound, ſince it ſuſtains one Pound of Mercury in the Tube: Therefore the ſuperior Column weighs one Pound. In ſhort, it hinders a Pound Weight, which is on the other Side in the Scale of the Balance, from preponderating.

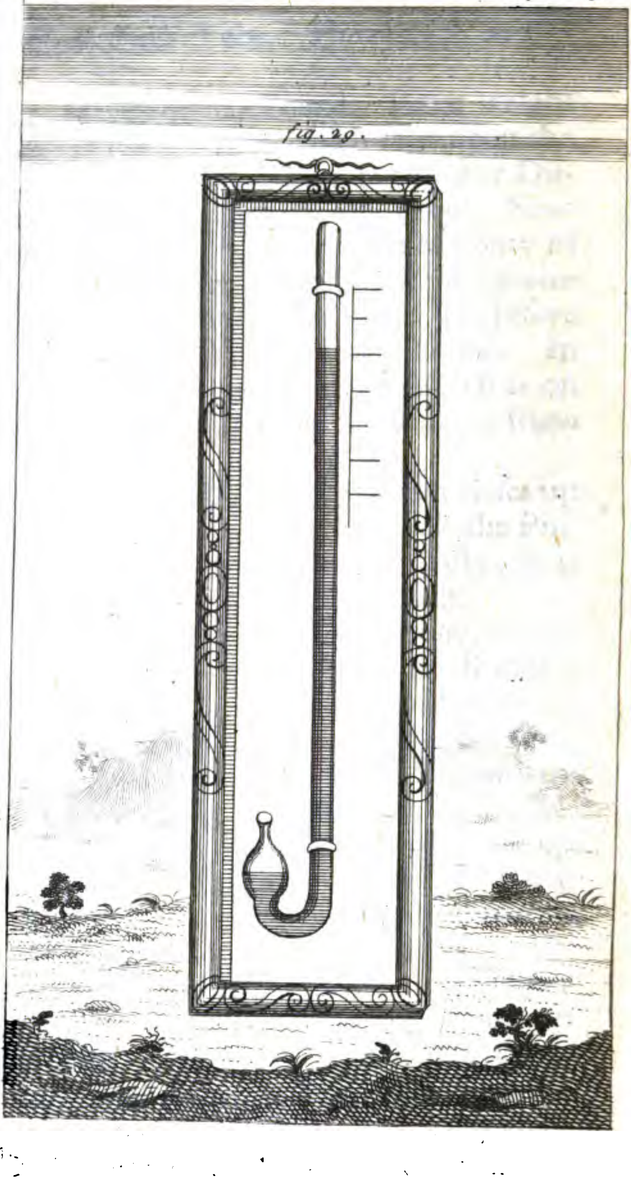
Eud. I bore the Bladder *(e)*, which cloſes up the Tube, with a Pin. I draw back the Pin. There is no more Mercury in the Tube; it is all ſunk into the inferior Veſſel already.

Ariſt. A Column of Air of one Pound, which enters through the little Hole of the Bladder, with one Pound of Mercury, has made a greater Weight than that of the external Column, which ſuſtained the one Pound of Mercury by deſcending upon the Mercury in the Veſſel. The greater Force ought to prevail, raiſe up the weaker, and deſcend. All the Mercury has obſerved the Laws of Nature; and here it is in the Veſſel.

Eud. Let us fill with this Mercury another Glaſs-Tube, one End of which is cloſed up without Vent. I invert it. There is the Mercury ſuſpended as in the firſt. I lift up the lower End as far as the Surface of the Mercu-

ry,

fig. 29.



ry, which floats in the Veſſel; a omy Clouds falls from the Tube. You ſee the res the At- up rapidly as far as the upper End, wn when ſometimes broke by ſo ſudden a Motion. Pray,

Ariſt. Whenever a Drop of Mercury co ure out of the Tube, the *Æquilibrium* ceaſes. The Air, becoming victorious all at once, gives a ſudden Impreſſion to the reſt of the Mercury, which makes it aſcend haſtily. Thus, when two Weights are in *Æquilibrium* in a Balance, take ſomething away quickly from the one Weight; the other will preſently outweigh, and rapidly elevate the diminiſhed Weight.

Eud. This Tube, which they commonly call the *Toricellian* Tube, becauſe *Toricellius* firſt invented it, is a true Barometer, when it contains Mercury; ſince it ſerves to meaſure the Gravity of the Air. Let an Enameller bend it at the lower End, and join a ſmall Phial to it, which affords Acceſs to the external Air: then hang it up perpendicularly upon a Board marked with Degrees, to the Height of between 27 and 28 Inches, or thereabouts, from the Level of the Mercury in the Phial, *Fig.* 29. It is a ſingle Barometer which informs you of fair Weather, Rain, Winds, Storms, Calm, or Tempeſt, and diſcovers to you beforehand the Danger or Safety, the Pleaſure or Toil of a Voyage or Walk. By what ſecret Charm does a Tube, filled with Quickſilver, diſcover Futurity?

Ariſt.

I do not well compre-
nd the Prognoſtics of
certain, as I think,
uces them.

e Barometer aſcends
s the Air is more
weighs leſs in rai-
in fair Weather; and
it begins to weigh more, when
Weather becomes fair. For which Reaſon the Mercury is lower in rainy Weather, and higher in fair Weather. Hence, if the Mercury deſcend, it is a Sign of Rain; if it aſcend, it is a Sign of fine Weather. Here is the Charm which makes us foreſee fine Weather or Rain, Calm or Tempeſt.

Ariſt. This ſecret Charm ſtill leaves ſome Uneaſineſs in my Mind. In fair Weather, the Air appears leſs charged with Vapours or Particles of Water. How then does it weigh more?

Eud. Then the Air appears leſs charged with Vapours; becauſe the Vapors being more attenuated by the Rays of the Sun, or by the Heat of the Earth, being more ſubtile, and diffuſed in the great Circles of the Atmoſphere, do leſs interrupt the Rays of Light. Nevertheleſs it is more charged; for then the Rivers and Fountains diminiſh, the Earth is dryer, and the Plants, Flowers and Fruits wither. Where are the Vapors, if not in the Atmoſphere?

Ariſt. What, when dull and gloomy Clouds veil the Heavens from my Eyes, does the Atmoſphere contain fewer Vapours, than when the Heaven is clear, ſerene, and ſmiling? Pray, what is it then that forms thoſe obſcure Clouds?

Eud. They are Vapours that deſcend from the more elevated and larger Circles; and which being more united in the lower and ſmaller Circles, obſtruct the Paſſage of the Light.

Ariſt. But ought not the Deſcent of Vapours to preſs and weigh down the Air, and conſequently make the Mercury to aſcend?

Eud. 1. The Deſcent of the inſenſible Vapours, which precedes the Rain, diſcharges the Air imperceptibly; hence the Mercury deſcends, and prognoſticates Rain.

2. The Deſcent of the Vapours, united into ſenſible Drops, makes the lateral Air to aſcend, whether it be by their Weight when they fall, or by the Efficacy of their Spring and Reflection at the End of their Fall. In ſhort, faſten two Bodies of different ſpecific Gravity to the two Ends of a Thread, a Bullet of Lead for Example, and a Ball of Cork; ſo that thoſe two Bodies may ſwim in a long Tube full of Liquor. Faſten the Tube perpendicularly to one of the *Radii* of a Ballance, and faſten an equal Weight to the other. Let this Weight and the Tube be in *Æquilibrium.* Cut the Thread which faſtens the Lead and Cork together; the Cork aſcends, and the Lead deſcends;

ſcends; the *Æquilibrium* is loſt; the Tube is elevated[l]. Why? Becauſe the Parts of the Liquor weigh leſs, when they are raiſed up by the Weight which deſcends. After the ſame Manner the Air being raiſed up by the Vapors which fall, ought to be lighter; being lighter, it permits the Mercury to fall. Thus the Mercury being ſunk, foretells the Fall of Vapors and Rain.

They affirm, 'tis true, that in the torrid Zone, which is between the Tropics, the Mercury aſcends continually in the Night, inſtead of deſcending; altho' the Vapors ariſe in the Day Time, and fall down again at Night. But in thoſe Regions, 1. The exceſſive Heat dilates the Air in an extraordinary Manner in the Day Time, and conſequently renders it lighter. 2. The Fermentations, cauſed by the Violence of Heat in the Surface of the Earth and Water, elevate the Air in the Day Time. 3. The Vapours and Exhalations that ſpring up on high, by the Force of theſe Fermentations, have leſs relative Gravity, than when they are in *Æquilibrium*; and compoſe, if I may ſay ſo, the ſame liquid Maſs with the Air.

Sometimes in this Countrey, a Wind being reflected, which blows from below upward, bears up the Air, renders it lighter, and produces on the Barometer the ſame Effect as Rain.

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[l] Hiſt. de l'Acad. 1711. p. 5.

Finally, upon the inferior Mercury of the Barometer I pour 14 Inches of Water; the Mercury aſcends one Inch in the Tube.

Ariſt. Becauſe an Inch of Mercury is in *Æquilibrio* with 14 Inches of Water.

Eud. Put into this Water the End of a Syringe, draw the Piſton, and the Water follows it.

Ariſt. Is it aſtoniſhing that the external Air, which weighs 28 Inches of Mercury, or thereabouts, makes the Water to aſcend, when by lifting up the Piſton you remove all Obſtacle to the riſing of the Water?

Eud. Is it the Air then, which alſo makes Water aſcend to about 32 Foot in attracting Pumps, when the lower End of the Barrel is in the Water, and one draws the Piſton?

Ariſt. The Air, which ſuſtains and elevates the Mercury to 28 Inches in the Barometer, ſuſtains and elevates the Water to 32 Foot, or thereabouts, in the attracting Pumps, if the Weight of 28 Inches of Mercury, and the Weight of 32 Foot of Water, are nearly equal: But they are nearly equal; ſince one Inch of Mercury, as we have ſaid, equiponderates with 14 Inches of Water: Therefore the Air ſuſtains and elevates Water to 32 Feet, or thereabouts, in attracting Pumps.

Eud. In the mean Time the more Water aſcends in the attracting Pump, the greater Reſiſtance we find made againſt the Force which lifts up the Piſton.

Ariſt. The more Water aſcends, the more does the Column of Air which bears it up employ of its Force to ſupport it; the more of its Force it employs for this Uſe, the leſs it has to counterballance the perpendicular Column, which falls upon the Piſton. The leſs that counterballances this, the more this preſerves of its Weight for oppoſing itſelf to the Elevation of the Piſton. Hence the more Water aſcends, the greater Reſiſtance one feels.

Eud. The Reſiſtance then which one feels, is not properly the Reſiſtance of the Water.

Ariſt. It is properly the Reſiſtance of the ſuperior Air.

Eud. The Reſiſtance ought to be felt then upon the Surface of the Hand, which draws the Piſton, and which is under the Column of Air.

Ariſt. That ought not to be, if the Surface of the Hand is equally preſſed contrary Ways by the external and internal Air; for according to the Laws of the Union of Soul and Body, the Soul does not feel but when ſome Change happens in the Body. Now the Surface of the Hand is equally preſſed contrary Ways, both by the internal and external Air; ſince the firſt puſhes back by its Elaſticity, as much as the other puſhes by its Weight: Therefore the Reſiſtance ought not to be felt upon the Hand which draws the Piſton.

Eud. It ought to make itſelf be felt when it is.

Ariſt. When it there cauſes any Change in the Organs, I grant it.

Eud. But to conclude, why is it felt in the Piſton?

Ariſt. It ought to be felt in the Piſton, if the Column which deſcends upon the Piſton employs more Force to thruſt it downward, than the lateral Column employs to thruſt it upward again; the Hand, which draws the Piſton a contrary Way, ought to feel this Exceſs of Force. But the Column which deſcends upon the Piſton, employs more Force to thruſt it downward; ſince in Order to thruſt it downward, it employs the Force which the lateral Column employs to bear up at once both the Water and the Piſton. Therefore, *&c.*

The Reſiſtance ought to be felt where the free Force of the Weight of the perpendicular Column is united. But it is united in the Piſton; for it is united in the Baſe, and this Baſe is the Surface of the Piſton.

Eud. Here is, I think, one Fact ſufficiently cleared up. Let us now obſerve ſome Marks of the Air's Gravity in the Air-Pump, *Fig.* 1. I fit to the Hole of the Copper-Plate the Orifice of a flat Bottle, caſed with Straw. At once pumping out the Air my Bottle is broke.

Ariſt. According to the Rules of Natural Philoſophy, the Bottle ought to break and fall into Shivers, as it does, if the two oppoſite Sides, which are, as it were, two oppoſite Planes, ought to approach one another: Now they ought to do it. For they cannot be impelled toward one another by two Columns of Air, whoſe Diameter is equal to their Diameters, without advancing toward one another; unleſs they be ſupported by an internal Force, equal to the Force which impels them. They are not ſupported after that Manner, ſince the Air is pumped out. Therefore, *&c.*

Eud. I pump the Air out of the Receiver. The Receiver is not broke to Pieces.

Ariſt. Its Parts being diſpoſed in Form of a Vault, and ſuſtained by one another, are Proof againſt the Gravity of the external Air.

Eud. In vain do I try to ſeparate the Receiver perpendicularly from the Machine.

Ariſt. The Action of the Gravity of the Air, diffuſed univerſally, retains them united.

Eud. Therefore it is the Action likewiſe of the Air's Gravity, which hinders my ſeparating perpendicularly theſe two poliſhed Marbles.

Ariſt. No doubt of it.

Eud. In ſhort, I ſuſpend them in the Receiver. — I pump the Air out at ſeveral Times. — The inferior Marble is ſeparated as of itſelf. That is becauſe it is no more ſuſtained by the Preſſure of the Air. Nevertheleſs I ſeparate them horizontally out of the Receiver, without any Obſtacle from the Preſſure of the Air.

Ariſt. When you endeavour to make them run, or ſlide upon one another, the Air behind them ſeconds your Effort, as much as the Air before them reſiſts it. Hence there is little Oppoſition to the horizontal Separation; but there is no Air between the two Marbles to ſecond their perpendicular Separation. You have the Preſſure of the Air, which unites them, to overcome without any Help.

Eud. Theſe Hemiſpheres void of Air, ſo famous, and which could ſcarcely be ſeparated by Horſes, would no longer aſtoniſh you.

Ariſt. No more than the two poliſhed Marbles. The Union both of the one and other, proceeds equally from the Weight and Preſſure of the external Air.

Eud. But are the two Columns then ſo very weighty, which anſwer to the two Hemiſpheres?

Ariſt. Let us ſuppoſe that the Diameter of each Hemiſphere is a Foot; the Column of Air, which anſwers to each Hemiſphere, weighs more than 2160 Pounds. It weighs more than a Column of 30 cubical Foot of Water, ſince it can ſupport 32. Now a Column of 30 cubical Foot of Water weighs 2160 Pounds; for a cubical Foot of Water weighs 72 Pounds; and 72 Pounds, multiplied by 30, give 2160 Pounds. Therefore the Column of Air, which anſwers to each Hemiſphere, weighs more than 2160 Pounds. What will it be, if you double the Diameter of each Hemiſphere?

Eud. Thus, I think, we have Facts enough to prove the Gravity of the Air, and that we inceſſantly bear a Weight of more than 2000 Pounds, without perceiving it. Let us ſee ſome Facts which particularly reſpect the Spring of the Air. But what do I hear? They are coming to interrupt us. To Morrow, *Ariſtus*, I ſhall expect you. I wiſh you would be here by five in the Morning, ſo much Pleaſure do I find in your Converſation.

CONVERSATION XXIII.

Upon the Effects of the Spring of the Air †.

I Was waiting for you, dear *Ariſtus*, in making Tryal of an excellent Air-Pump. — The Piſton deſcends at firſt without any Obſtacle.

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† It has been ſhewn, that the Air has the Properties of other Liquids; but beſides it has another Property, which is, that it can take up a greater or leſſer Space, according as it is compreſſed with different Force; and as ſoon as that Force is diminiſhed, it expands itſelf. By Reaſon of the Analogy of this Effect with the Elaſticity of Bodies, this Property of the Air is called its *Elaſticity*.
The Elaſticity of the Air is as its Denſity; for this laſt is inverſly as the Space taken up by the Air, and therefore as the Force compreſſing the Air, which is equal to that by which the Air endeavours to expand itſelf, but this Force is its Elaſticity. *S. Graveſande's Elem. Phyſ.* The Air is loaded by the Weight of the whole Atmoſphere preſſing every Way, according to the Nature of a Liquid; the Force it exerts does no Way depend upon its Elaſticity; becauſe whether you ſuppoſe Elaſticity or not, that Force which ariſes from the Weight of the Atmoſphere, and is equal to it, can no Way be changed: but as the Air is elaſtic, it is reduced to ſuch a Space by the Weight of the Atmoſphere, as that the Elaſticity, which reacts againſt the compreſſing Weight, is equal to that Weight. But the Elaſticity encreaſes and diminiſhes as the Diſtance of the Particles diminiſhes or increaſes, and it is no Matter whether the Air be retained in a certain Space, by the Weight of the Atmoſphere, or any other Way. For in either Caſe it will endeavour to expand it ſelf with the ſame Force, and preſs every Way. Therefore if the Air near the Earth be included in any Veſſel, without altering its Denſity, the Preſſure of the included Air will be equal to the Weight of the whole

Ariſt. Becauſe the Dilation of the internal Air, which deſcends into the Pump, puſhes the Piſton downward, with a Force almoſt equal to the Reſiſtance of the external Air.

Eud. The more I pump the internal Air, the more the Piſton ſeems to reſiſt. —

Ariſt. The more you pump the internal Air, that which remains has a freer Space, and is more dilated; the more it is dilated, the leſs Force it has to ſecond you; the leſs it ſeconds you, the more you feel the Reſiſtance of the external Air; the more you feel that, the more the Piſton ſeems to reſiſt.

Eud. I draw the Piſton again; you ſee a ſmall Rain, and the Sides of the Receiver tarniſhed and obſcured within.

Ariſt. The internal Air, which is rarified ſuddenly, puſhes and ſhakes the imperceptible Vapors which flutter in the ſame Air; and if it is in a certain Degree of Rarefaction, it has no longer Force enough to ſuſtain them. Thoſe Vapors being united in the Succeſſion, and in their Fall, fall down in Rain. Many of them

whole Atmoſphere. Thus we find Mercury ſuſtained to the ſame Height by the elaſtic Force of Air, included in a Glaſs Veſſel, no Way communicating with the external Air, as by the Weight of the whole Atmoſphere. *Id. Ibid.*

The Effects of the Elaſticity of the Air are like thoſe of its Gravity; and included Air acts by its Elaſticity, just as Air not included by its Weight.

The Particles whereof Air conſiſts do not touch each other; their repelling Force keeps them apart; and the Force wherewith they endeavour to recede, increaſes in the ſame *Ratio* wherein the Diſtance of the Particles is diminiſhed.

being

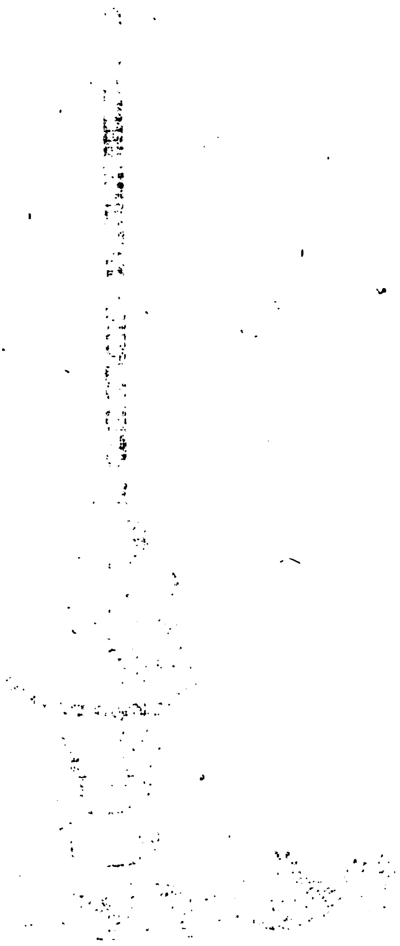
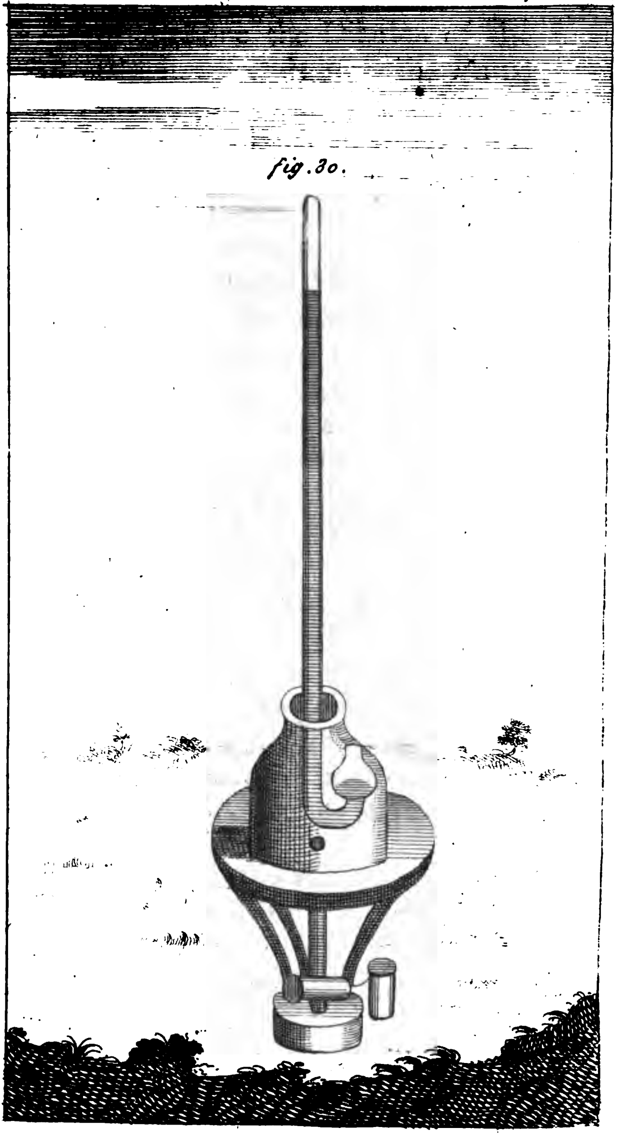


fig. 30.



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being thrown upon the Sides of the Receiver, tarniſh it inwardly and obſcure it, ſhutting up the Paſſages of Light.

Eud. When the Piſton has deſcended, I leave it at Liberty. It aſcends as of itſelf.

Ariſt. Becauſe it is thruſt back by the external Air, without finding in the rarefied Air of the Barrel, a Reſiſtance equal to the Force which thruſts it back.

Eud. I let the external Air enter again into the Receiver by turning the Key, and by the Pipe of Communication; the Receiver is detached and obeys.

Ariſt. Becauſe the Air being returned, puſhes it upward with an elaſtic Force, equal to the Action of the Gravity of the external Air, which puſhes it downward.

Eud. I have made the Tube of a Barometer paſs thro' the bored Top of another Receiver, which I place upon the Copper-Plate inſtead of the firſt. You ſee the Mercury at its ordinary Height, in a very ſmall Space, *Fig.* 30.

Ariſt. The internal Air retains it there by its Spring.

Eud. I pump out the Air, and the Mercury deſcends.

Ariſt. Becauſe the dilated Air, which remains, having no longer the ſame Force, does no longer ſuſtain the ſame Weight.

Eud. I let the Air enter again. The Mercury aſcends again.

Ariſt. The internal Air, being eſtabliſhed again in its former State by this Return, has the ſame Force which it had before; the ſame Force produces the ſame Effect, replaces and ſuſtains the Mercury at the ſame Height.

Eud. I place under another Receiver an old and ſhrivelled Apple, and a flaggy Bladder, whoſe Neck is well tied; I pump the Air. — The Bladder is inflated, and the ſhrivelled Apple appears plump to the Eye. — Is it not an Apple freſh gathered?

Ariſt. The Air, which is within the Apple and Bladder, being no longer compreſſed by the external Air, is dilated; and by its Dilatation inflates the Bladder, and produces this Species of new Fruit.

Eud. Let us permit the Air to enter again, the inflated Bladder becomes flaggy, and the Apple is ſhrivelled and loſes its new freſhneſs.

Ariſt. The Air which enters, being more compreſſed and ſtronger than the dilated Air of the Apple and Bladder, preſſes and contracts their Extremities. Thus the Bladder and Apple reſume their Wrinkles.

Eud. Let us place a Glaſs of Beer under a ſmall Receiver. — Pump the Air. — Here are Thouſands of ſmall Bubbles which aſcend. — Pump again. — The Beer froths.

Ariſt. Thouſands of Particles of Air, which remained ſhut up and intangled in the Interſtices of the Beer, being at laſt delivered from the Preſſure of the ſuperior Air, are diſengaged, dilated and inflated. Being inflated, they have thereby much more relative Levity; and being forced to aſcend by the Gravity of the Beer, they rapidly reach the Surface of the Liquor. Every Bubble of Air raiſes up, and carries along with it a Pellicule, a very minute Surface of Liquor, and is wrapped up in it. Hence thoſe ſmall, white and numerous Bubbles, which ſwim upon the Beer. Thus the Beer lathers.

Eud. Inſtead of the Beer I put a large Glaſs, almoſt half full of warm Water. I pump out the Air at different Times. The Water riſes up with great Bubblings, ſprings up into the Vacuity, and boils more ſtrongly than if it were over a great Fire. The Spirit of Wine would produce the ſame Effect.

Ariſt. That which makes the Beer lather, makes alſo Water and Spirit of Wine to boil. Spirit of Wine and Water are impregnated with Air. This Air, being eaſed of half the Weight which preſſed it, is ſet at Liberty, and unfolds its Spires and Plates. An Exceſs of relative Levity makes it yield and aſcend haſtily. Its rapid Motion bears up, and throws out a Number of liquid Surfaces. Thus warm Water and Spirit of Wine boil without Fire.

Eud. But why does warm Water boil rather than cold Water?

Ariſt. Becauſe the Parts of warm Water being agitated, divided and diminiſhed by the

Action of the Heat, leave the Particles of Air, already heated a little and dilated, freer Paſſages to diſengage themſelves.

Eud. The Bubbles of Air augment in Bulk, and in Proportion as they approach the Surface.

Ariſt. Becauſe in Proportion as they aſcend, having leſs Weight to ſuſtain, they are dilated.

Eud. Let us pierce the End of an Egg. — I put it into a ſmall Glaſs, with the pierced End downward. Pump out the Air. — You ſee the liquid Matter come almoſt all out from the Shell. — Let the Air return. — The Matter diſappears.

Ariſt. After the iſſuing out of the external Air, the Spring of the internal Air has dilated the liquid Matter, and driven it out of the Shell. After the Return of the external Air, the internal Air being ſhut up in its former State by a ſuperior Force, has left the Place free to the liquid Matter. This Matter being thruſt back, reenters the Shell, where all is in *Æquilibrium* with the Air of the Receiver.

Eud. Pour Water into a larger Glaſs. Upon the Surface of the Water I put a Spunge impregnated with Water, and cover it with the Receiver. Pump out the Air. The Spunge is ſomewhat elevated. Permit the Air to enter again. The Spunge ſinks. Pump again. The Spunge aſcends and ſwims above.

Ariſt. 1. When I pump the firſt Time, the Air contained in the Spunge finding itſelf more free, is dilated and comes out, in Part at leaſt. What Air remains in the Spunge, altho' it be much weaker than before, is ſufficient to give a greater Bulk to the Spunge by its Dilation. This Exceſs of Bulk renders it lighter. Being lighter, it aſcends a little. 2. I make the external Air to re-enter. This Air being much ſtronger than the diminiſhed and weakened Air of the Spunge, compreſſes it. By compreſſing it, the Spunge is contracted into a leſs Bulk, and more compact than it was before. By that Means the Spunge becoming more weighty than an equal Volume of Water, ſinks. 3. Whenever I pump again, the internal Air not having the Preſſure of the pumped Air to ſuſtain any longer, is dilated again, and dilates the Spunge. The Spunge being dilated and more light, recovers the Surface of the Water. I need only continue the ſame Mechaniſm, and the Spunge will continue its Diverſion by the ſame Reaſon.

Eud. Do you ſee, *Ariſtus*, this other Species of ſmall Receiver? It is a Cupping-Glaſs. They apply it full of the light Flame of a little Flax upon Cicatrices made on the Shoulder of a Man in a Lethargy. Whenever the Flame is extinguiſhed, the Fleſh, which anſwers to the hollow of the Cupping-Glaſs, is inflated, and the Blood thrown out.

Ariſt. The Flame expels much Air from the Cupping-Glaſs, and rarefies the reſt in an extraordinary Manner. It is extinguiſhed? The

Air, which is in the Blood and Fleſh, and which has loſt nothing of its Force, is ſtronger than the dilated Air of the Cupping-Glaſs, and is extended. This Extenſion inflates the Fleſh, and rarifies the Blood; the Blood being rarified is thrown forth.

Eud. One Fact more of the Spring of the Air, which pleaſes the Eye without hurting the Imagination. You ſee this ſmall enamelled Figure of a Man (*a*), *Fig.* 31. It is full of Air. It has in the Leg a ſmall Eminence, bored through and through. I fill this Glaſs-Tube with Water by the lower End. The little Figure immediately ſwims, then it deſcends, aſcends again, reſts, whirls about, dances, and repeats the ſame Scene at Pleaſure.

Ariſt. Let us ſee the Experiment.

Eud. You ſee the little Figure ſwim above.

Ariſt. The Reaſon is, becauſe the internal Air makes with the enamelled Picture, a Bulk lighter than an equal Bulk of Water.

Eud. I preſs with my Thumb the Orifice of the Tube. The little Man is plunged to the Bottom.

Ariſt. The Water being compreſſed by the Action of the Thumb, enters into the little Hole of the Leg, compreſſes the internal Air, and renders the Bulk more heavy. Being more heavy, it ſinks to the Bottom.

Eud. I ceaſe to preſs the Water, always cloſing up the Orifice of the Tube with my Thumb.

fig. 32

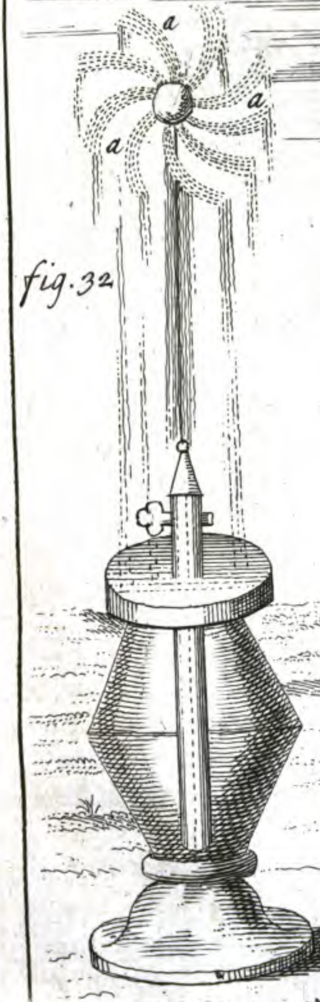
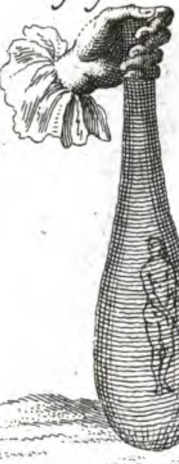


fig. 31



UNIV.

Thumb. The little enamelled Man aſcends again.

Ariſt. The Water, which ceaſes to be compreſſed by the Thumb, yields to the Spring of the internal Air, which is dilated; it comes out of the Leg. The Figure becomes lighter. Being lighter, it is thruſt back toward the Surface of the Water.

Eud. While it aſcends again, I ſay but one Word, and it reſts in the Middle of its Journey.

Ariſt. The Word alone would be very ineffectual; but you ſtay your Thumb upon the Surface of the Water; you preſs it ſo, that it flows into the ſmall Hole of the Leg, preciſely in ſuch a Quantity, as is neceſſary for putting the enamelled Figure into an *Æquilibrium.* This, I believe, is the Charm, which at once ſtops it half Way.

Eud. Is it alſo then my Thumb, which determines it at once to whirl about, and to dance in the Middle of the Tube?

Ariſt. While at different Times you ſink and raiſe your Thumb with a certain Quickneſs, the Air and Water are alternately victorious in the Hole of the Leg. In this Sort of Conflict they haſtily daſh againſt the ſmall Eminence, and give it a Direction to go toward the Right or Left. The Figure cannot follow this Direction; the Obſtacle of the Water impedes it. But by turning about, it may yield itſelf to the Motion which it has received; it turns about according to your Laws of Motion, it whirls round, dances mechanically; and this is continually in Appearance with ſome Succeſs.

Eud. Now with the Breath alone, or with a Pair of Bellows, let us condenſe the Air upon the Water in a cloſe Veſſel; out of which the Water may ſpout by a Tube, one End whereof deſcends as far as the Bottom of the Veſſel, while a moveable Key opens and ſhuts the other End, *Fig.* 32. The Water ſpouts up, and makes an artificial Fountain. Upon the Water ſpouting up I place a Wax-Ball, or rather a Copper-Ball, hollow and very thin. The Water which touches it, ſuſtains it, makes it to turn about, and turns about itſelf, till it get off and be thrown out in Streams, which are like ſo many Tangents *(a a a)*.

Ariſt. The Water being compreſſed by the internal Air extraordinarily condenſed, and thruſt back by the external Air, which is only in its ordinary Condenſation, yields to the greater Force, overcomes the weaker, and is darted out into the Air. The Force of the Water ſuſtains the Ball, which is of Copper, but very thin, and full of Air. The Water which ſtrikes it, but not preciſely in the Middle, makes it turn round; and flowing upon the Surface, where it ſticks a little, turns itſelf round, till the Force which makes it turn, detaches it. Then it follows the ſecond general Rule of Motion, and goes off by the Tangent, as all Bodies do which are moved circularly, whenever they are at Liberty.

Eud.

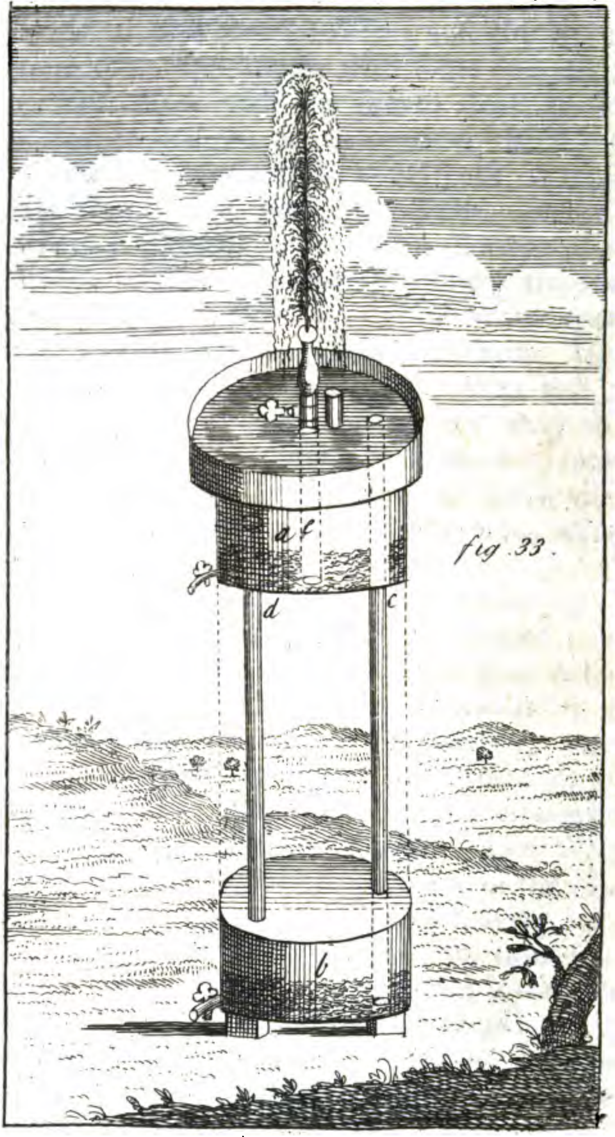


fig 33.

Eud. Let us place the ſame Veſſel over the Fire, without condenſing the internal Air; the Water ſpouts up.

Ariſt. The Heat dilates the internal Air; the Air being dilated forces the Water to ſpout up. This is a Species of *Æolipile.*

Eud. Imagine now, or rather conſider two Pipes of Tin, perpendicular to the Horizon, open at the two Ends, and ſunk into two Sorts of Drums of the ſame Matter *(a, b,) Fig.* 33. The one of the Tubes *(c)* pierces the ſuperior Drum *(a)*, quite through, and deſcends almoſt to the Bottom of the inferior Drum *(b)*; the other Tube *(d)*, which only penetrates the ſuperior Plane of the inferior Drum, penetrates into the other Drum as far as the ſuperior Plane. In the Middle of the ſuperior Drum is a ſmall Tube *(e)*, which deſcends almoſt to the Bottom of the ſame Drum. This Machine they call the Fountain of *Heron*. By the Tube in the Middle, I fill the upper Drum with Wine. I leave therein no Paſſage but through a little pyramidal Pipe. Then by the Pipe which pierces the upper Drum quite through, I pour in Water into the lower Drum. There is Wine which iſſues out of the other, and ſprings up into the Air. Is it not Magic that makes Wine to ſpout out from the Boſom of Water itſelf?

Ariſt. The Water being poured through the Tube fills the inferior Drum. When the Drum is filled with Water, the Air which filled it removes through the ſecond Tube, is diffuſed and condenſed above the Wine in the ſuperior Drum. The Wine being impelled by the Spring of the Air extraordinarily condenſed, and finding a Paſſage by the inferior and the ſuperior Ends of the pyramidal Tube, iſſues out with ſo much the more Velocity, as it paſſes from a larger Place through a ſtraiter Vent. It ſprings up, and is darted far above its Source; and the Spring of the Air is the ſecret Charm, which ſeems to make the Wine ſpout out from the Boſom of Water itſelf.

Eud. After this, nothing ſeems to be more evident in natural Philoſophy than the Spring of the Air; a Spring ſo much the more perfect, becauſe the Time of its Tenſion does not change it, as that of Wood or Steel. For *M. de Roberval*, of the Royal Academy of Sciences, having let his Air-Gun remain charged with condenſed Air for the Space of ſixteen Years; this Air, being at laſt ſet at Liberty, appeared to have loſt nothing of its elaſtic Force, and produced the ſame Effect which it would have done at firſt[m].

Ariſt. I do not demand a Demonſtration; I would only have a plauſible Reaſon of this Fact. *Eud.* 1. The Air being a more ſimple Body than other elaſtic Bodies, ought to be changed with the greater Difficulty. 2. The ſubtile Matter flowing alone through the Pores or Interſtices of the Air, without being charged with Air, or Spirits of Nitre, or groſſer Corpuſcles, as it is when it penetrates other Bodies, ought to damage the Air leſs. 3. In a Word, the ſmall Branches of condenſed Air make a Maſs, whoſe united Forces preſerve it from the Action of the ſubtile Matter. Hitherto we have ſeen, I think, Facts enough peculiar to Gravity, and Facts enough peculiar to the Spring of the Air; let us ſee ſome Facts which ſeem to regard both the Gravity and the Spring at the ſame Time.

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[m] Hiſt. de l'Acad. 1695. p. 368.

Ariſt. Muſt I my ſelf, *Eudoxus*, interrupt a Converſation, wherein you give me ſo much Pleaſure? But a Duty of Friendſhip calls me elſewhere. At one o' Clock in the Afternoon I ſhall wait on you here.

Eud. An honeſt Man does not neglect a friendly Office; ſhould a Philoſopher then decline it? Philoſophy knows how to accommodate itſelf to the Laws of ſound Morality.

CONVERSATION XXIV.

Upon divers curious Effects of Gravity and Elaſticity of the Air in different Bodies.

Eud. WILL you believe it, *Ariſtus?* The Air inſinuates itſelf, and is, in ſome Sort, diſſolved in Water; eſpecially in boiled Water. Boil ſome Water for about an Hour. Let it cool again: Then fill a Phial with it, whoſe Belly is very round. Cloſe it up with your Finger in ſuch ſort, that you may let the Air enter into it, about the Bigneſs of a Filberd. Turn it topſy turvy. Plunge the End of it into a Glaſs full of the ſame Water: In three or four Days this Air will be almoſt wholly loſt in the Liquor. I put a ſmall Bubble of Air of two or three Lines into a Glaſs Phial, full of River Water, which has not boiled. The Bubble of Air is alſo loſt in the Water; but more than fifteen Days are required, to make it diſappear[n].

Spirit of Wine, out of which the Air is gone, ſucks it up in leſs than three Hours *.

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[n] Mariote de la Nature de l'Air, p. 97. 106.

* Mariote, p. 132.

Ariſt. In this Experiment the Weight and Preſſure of the external Air, which can elevate 32 Foot of Water, puſhes the Water of the Phial againſt the Bubble of Air, which ſwims above. The Bubble of Air thruſts back the Water by the Efficacy of its Spring. In this reciprocal Action the Particles of Air gradually divide the Particles of Water; the Particles of Water divide the Particles of Air: The one finds Acceſs into the Interſtices of the other. Thus the Air penetrates, is diſſolved, and loſt after ſome Days in boiled Water.

By the ſame Reaſon, the Air is loſt in Water, which has not boiled: But the Effect is not ſo ſpeedy, becauſe the Particles of boiled Water being divided and diminiſhed by the Agitation of the Heat, find a more eaſy Acceſs into the Interſtices of the Particles of Air, and mutually afford them more eaſie Acceſs into their own Interſtices, than Water which has never been boiled. By this one ſufficiently underſtands why Spirit of Wine ſucks up Air ſo quickly.

Eud. Nevertheleſs Air is mixed more difficultly with Water, than Wine. I place in the Bottom of a Veſſel, full of Water, this Bottle full of Air, whoſe Neck is three or four Lines wide. No Air comes out of it, no Water enters into it. I fill the Bottle with pure Wine. The Water penetrates the Wine, and the Wine the Water. You ſee it open itſelf a Paſſage through a heavier Liquor, and gain the Surface of the Water [o].

Ariſt. The Particles of Air are ſmall, minute, and fine; but ramous, according to the Definition which you have given of them. Wherefore thoſe Particles intangled in one another, in the ſmall Neck, make a ſmall uniform and ſmooth Surface, and ſuſtain the Water by their Spring ſo much the more eaſily; becauſe the Water preſſing equally and at once all the Parts of the ſmall uniform and ſmooth Surface finds no Acceſs into it, nor makes Columns unequally weighty with the inferior Air, which might give Place to one another. Hence the Water does not enter into the Bottle; nor does the Air come out of it. But the Particles of Wine, as well as thoſe of Water, are more groſs, ſolid, and leſs uniform. They make a Surface leſs ſmooth, afford Acceſs into one another, rub, touch, and agitate one another in more Parts, and make more Columns of unequal Force. Hence Water being heavier than Wine, inſinuates itſelf, deſcends, and makes the Wine to aſcend by ſmall Streams.

Eud. But finally, do you believe that the Air has the ſame Bulk in Water as without it?

Ariſt. It ought to be more contracted in Water, ſince therein it is charged with a greater Weight.

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[o] Mariote de la Nature de l'Air, p. 94.

Eud. Accordingly *M. Mariote* has obſerved that the Air, which he had expreſſed from a Drop of hot Water, contained, when cold again, eight or ten Times more Space than a Drop of the ſame Water [p]. According to the Principles and Calculation of this ſkilful Member of the Academy, the Air may be dilated more than four Thouſand Times beyond what it is in Liquors and near the Earth [q].

Hence, Air which is more condenſed in Liquors, Plants, Flowers and Fruits, than without them, cauſes Evaporations by the extraordinary Effects which it makes in Order to extend itſelf; and at laſt contributes to the Corruption of thoſe Bodies. Wine loſes its Spirit; Flowers decay; Fruits loſe their Sap, become inſipid, and putrifie. Theſe Bodies commonly are better preſerved in cloſe Places. Herbs, which would wither in leſs than an Hour in the open Air, remain freſh two or three Days when preſſed between two Linnen Cloths. Put Cherries into a ſmall Phial in the Month of *June.* Cloſe up the Mouth with red and viſcous Wax; and at the End of nine Days you will find the Cherries ſtill intire, and of the ſame Colour [r]. The Leaves which compoſe the *Calix* of a Tulip, preſerve their Shades and the Livelineſs of their Colours in a Book. Blood contained in a ſmall Matraſs hermetically ſealed up, has been ſeen to preſerve a fine Colour and its Liquidity for the Space of ten Years[s]. The Reaſon is, becauſe the Air of thoſe Bodies, finding more Reſiſtance made to its Dilatation in cloſe Places, produces fewer Evaporations, and the Action of the external Air, commonly charged with heterogeneous Corpuſcles, cauſes leſs Change in it.

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[p] Mariote de la Nature de l'Air, p. 111.

[q] Mariote de la Nature de l'Air, p. 170, 177.

[r] Ibid. p. 223.

But does this Air which inſinuates itſelf ſo ſubtly into different Bodies, paſs through Paper? Here's an Experiment which will convince us.— Upon the upper End of a Barometer, whoſe two Ends are open, I glue a ſmall Circle of Paper, with a Mixture of Wax and Roſin; ſo that the Air cannot enter but through the Paper itſelf. I pour between 15 and 16 Inches of Mercury into the Tube, and invert it after the uſual Manner. The Mercury deſcends ſuddenly to a certain Point; then it ſeems to ſtop. But in a ſhort Time it deſcends more ſlowly, till it be almoſt on a Level with the Mercury into which the lower End is plunged[t].

Ariſt. 1. The Mercury deſcends ſuddenly to a certain Point, becauſe with the Spring of the internal Air it makes a ſtronger Column than the external one. 2. It ſtops in Appearance; becauſe the internal Air being dilated, and the Mercury having fallen down, are in *Æquilibrium* with the external Air. 3. But in a ſhort Time the Mercury begins again to run gently; becauſe the external Air enters through the Pores of the Paper. 4. The Mercury deſcends gradually to the Level, becauſe the leaſt Exceſs of Force in the Air is ſufficient to find ſome Paſſages in the Paper.

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[s] p. 221. [t] Mem. de l'Acad. 1714. p. 59.

Eud. If I make Uſe of fine Paper, the Mercury deſcends the more ſwiftly.

Ariſt. That is becauſe in the fine Paper the Air finds more open Pores.

Eud. But proportionally as the Mercury deſcends, it deſcends more ſlowly.

Ariſt. In Proportion as it deſcends, the Column, which ſuſtains it, having leſs Mercury to ſuſtain, ſupports the Column, which ponderates upon the Paper, ſo much the more. This being more ſupported, makes leſs Effort in Order to paſs through the Paper, which oppoſes its Paſſage. With a leſs Effort, it penetrates more ſlowly. The Mercury being impelled more ſlowly, deſcends ſo much the ſlower.

Eud. I ſoak the Paper with Water. The Mercury remains ſenſibly ſuſpended, until the Paper begins to dry.

Ariſt. Becauſe the Water ſtops up the Pores of the Paper, and hinders the external Air from entering ſenſibly into the Tube.

Eud. Indeed, Seamen, when they have a Mind to ſail more ſwiftly, wet the Sails; that ſo the Water ſtopping the Interſtices of the Sails may ſhut up the Paſſage of the Wind, and that the Wind or agitated Air may puſh the

Sails with all its Force, and no Part of it paſs unprofitably through the Pores.

But the Air, which is in the Pores of the Paper, does not hinder Water to paſs through; why then does not Water let Air paſs through?

Ariſt. Air, which is finer than Water, is not ſufficiently attached to the internal Surfaces of the Paper, nor has Conſiſtence enough to ſuſtain the Gravity of Water that is more weighty and ſolid; it lets it paſs through. The Water being more ſolid and groſs, which wets, ſoaks, and lengthens the Paper, is ſufficiently ſupported by the unequal Surfaces of the Pores; it has Conſiſtence enough for ſuſtaining the Gravity and Effort of the external Air, and ſtops it.

Eud. Is the Air, ſay you, finer than Water? Nevertheleſs theſe two Liquids being protruded by the ſame Force, the laſt in certain Circumſtances paſſes through Places, which the firſt cannot. Inſtead of Paper I cover the Top of the Barometer with a Hog's Bladder. The Air alone does not penetrate the Bladder, but Water penetrates it[u].

Ariſt. That is, becauſe the Exceſs of Solidity, which is in the Particles of Water, prevailing over the Exceſs of Tenuity which is in the Particles of Air, thoſe have Motion and Force enough to open the Texture of the Bladder, while theſe, being retarded by their ſmall

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[u] Mem. de l'Acad. 1714. p. 61.

Branches, have not. In ſhort, Water wets, ſoaks, and lengthens the Bladder.

Eud. A Fact renders your Sentiment plauſible. The Particles of Water, which penetrate the Bladder, bring Air into the Barometer[*]. This Air they contain in themſelves: Therefore they are more groſs than the Particles of Air: Notwithſtanding they paſs through Interſtices, which the Particles of Air alone do not paſs through; therefore it is the Exceſs of the Solidity of the firſt, which makes them find a Paſſage, where the other find none, notwithſtanding their exceſſive Smallneſs.

Hitherto we have ſpoken of the groſs Air, which forms Speech itſelf, as we ſhall one Day ſee. Let us conclude our Converſation with a Fact which reſpects a finer Air.

With a Tube they take up a little of the melted Matter, whereof Glaſſes are made[‡]. You let it run and fall into a Pail full of Water; and becauſe this Matter is very viſcous, the inferior Part being thicker and heavier flows without being wholly detached, and is lengthened out in Form of a Tear. This ſort of Tear is ſometimes called the *Lacryma* of *Pruſſia*, and ſometimes the *Lacryma* of *Holland*. The Tear, which falls all red into the Water, is cooled therein; here is one, *Fig.* 34. I ſtrike with an Hammer the thickeſt Part of it *(d)*, or the Head of the Tear, without its breaking.

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[*] Ibid. p. 62.

[‡] Becauſe Glaſs is a Body which has a Power of Springing; it is probable, that this Glaſs-Drop is broke in the ſame Manner, as a Steel Bow burſts in Pieces ſometimes, when it is looſened on a ſudden, *viz.* by the too great Celerity and Force of that Motion which ariſes from the mutual Attraction of its Parts. For its Parts from the Center to the Circumference, ſeem to be like ſo many Bows bent. And thence perhaps it is, that after it is burſt to Pieces, its Fiſſures are diſpoſed like ſo many *Radii* drawn from the Axis to the Superficies, as Mr. *Hook* obſerved in a Glaſs Drop covered over with Glue: *See Hook's Micrography Obſerv.* 7. *Clarke's Rohault.*

Ariſt. I am not aſtoniſhed at it. The Parts which are ſtruck, being diſpoſed in Form of a Vault, and ſupporting one another, ought to be Proof againſt your Blows.

Eud. But I break the finer Part *(b)*, or Tail of the Glaſs Tear. — You ſee the whole Tear fly aſunder at once into white Duſt two or three Foot round about *.

Ariſt. Doubtleſs the Fact is ſurprizing. Notwithſtanding I think that, by Favour of the Lights which I owe to you, I diſcern the Cauſe of it in a finer Air, which ſuddenly paſſing from a larger Space into the open Pores of the broken Tail, runs rapidly into a Thouſand and Thouſand ſmall Cells, which grow wider and wider toward the Middle, then narrower and narrower toward the Extremities, and which the Irruption of the Air drives aſunder by the Efficacy of its Spring and accelerated Motion.

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* Mar. de la nat. de l'Air, p. 64.

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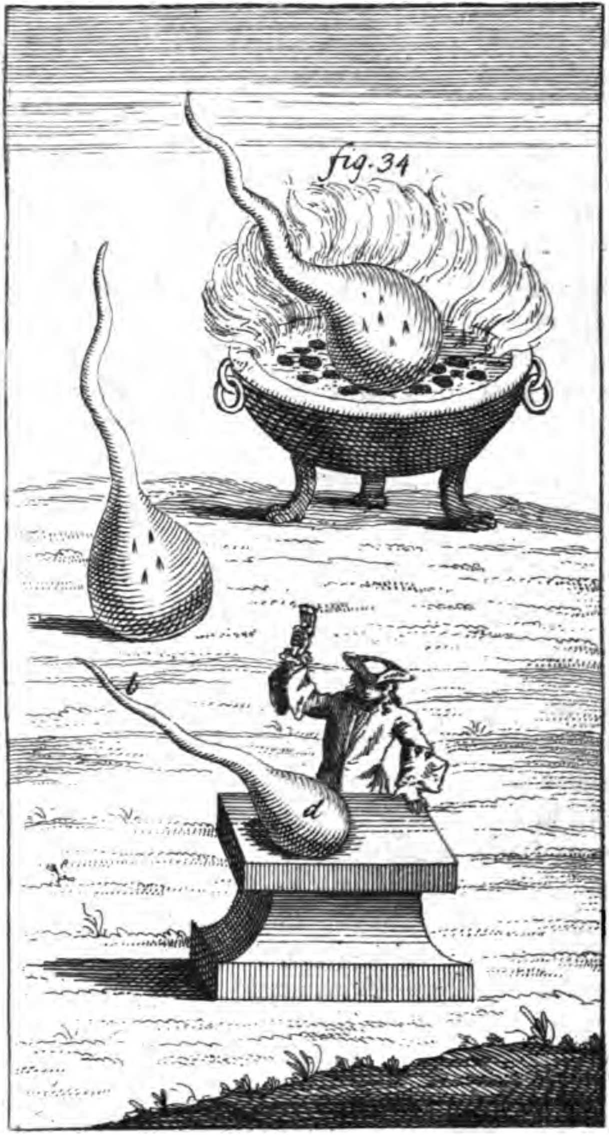
fig. 34
b
d

Whenever the Tear falls into the Water, the Particles of its Surface being ſuddenly ſeized with the cold of the Water, are cooled again and hardened immediately, while the internal Parts being extraordinarily dilated by the Heat and by an Air that is dilated itſelf, are ſtill red. The Parts of the Surface being cooled at once, are neither drawn near enough one another, nor well faſtened together, nor can they approach the Center any more. Hence, when the internal Parts come to be cooled, in Proportion as they are diſtant from the Surface, they leave ſmaller Interſtices toward the Surface, and greater toward the Middle. Theſe Interſtices only contain a rarified Air: For which Reaſon, when the fine Air finds an Entry through the Pores of the broken Tail, it enters briſkly into the internal and more ſpacious Interſtices; thence it drives out a more ſubtile Matter; and from the Middle of a Thouſand Cellules, the ſmall *Laminæ* of fine Air are rapidly hurried toward the Extremities, with an Acceleration of Velocity, and like ſo many Wedges, through Paſſages which conſtantly grow ſtraiter. This impetuous and ſudden Effort enlarges the Pores, and ſeparates the Parts, already but badly united. The Suddenneſs of the Shock darts out the Particles toward a Thouſand different Parts. Thus the Drop is crumbled into Duſt.

This Reaſon ſeems to me ſo much the more probable, becauſe the Air, which ſuddenly finds Acceſs through the lower End of a Barometer in an Experiment, throws the Mercury upward with ſo great a Violence, as you were ſaying not long ago, that ſometimes it breaks even the Tube itſelf.

Eud. Many Circumſtances confirm your Sentiment. For 1. The Tears, which are cooled in the Air, do not break. Why? Becauſe their Particles, which are cooled ſlowly, almoſt in the ſame Time, and equally, are united, and make the Air within reſume a Condenſation, equal almoſt to that of the Air without.

2. Drops that are nealed, no more break than thoſe cooled in the Air; becauſe the Air from without finding the Matter of thoſe Tears ſoftened by the Heat, makes it re-enter within, compreſſes the internal Air, and by that Means prevents the Irruption and impetuous ſhaking of the fine Air, which breaks the Drops that are cooled in Water.

3. Put a Pin into the large Bubbles, half poliſhed with Preſs-Sand, upon a Plate of Steel, or elſe with very fine Powder of Emery: Sometimes the Tear is broke; the Pin which makes the external Air to enter, cauſes the breaking of the Drop. Sometimes alſo it is broken when the Pin is no longer in it, and when one ceaſes to make any more the leaſt Effort[y].

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[y] Mar. de la nat. de l'Air, p. 72.

The Drops of Glaſs are broken in the Air-pump with a greater Effect ſo as to produce Light [z]; becauſe there remains fine Air enough to break them by its ſudden and violent Irruption, and becauſe there is much leſs groſs Air, which might hinder the ſcattering of the detached Fragments.

Finally, when you deſire it, *Ariſtus*, we will ſee in Syphons and capillary Tubes ſome ſingular Facts, wherein the Gravity and Spring of the Air, and the ſubtile Matter itſelf, appear to have a great Share.

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[z] Hiſt. de l'Acad. 1692. p. 307.

CONVERSATION XXV.

Concerning Syphons and Capillary Tubes.

Eud. LET us continue our Experiments, *Ariſtus.* I take a Syphon. It is a crooked Glaſs, one of whoſe Branches is ſhorter than the other, *Fig.* 35. I put the ſhorter one into the Water. The Water remains calm. I ſuck the Air from the two Branches. You ſee the Water flow.

Ariſt. Before you ſuck the internal Air, it oppoſes the Elevation of the Water with a Force equal to the Force of the external Air, which preſſes and ſtrives to elevate the Water in the Syphon; and the Water remains in *Æquilibrium* between two equal Forces. But after you have ſucked the internal Air, the Water that anſwers to the Syphon being preſſed by the Weight of the external Air, which would elevate it to 32 Foot, and being no longer retained by an equal Force, aſcends through the ſmall Branch as far as the Communication of the two Branches. Then the Efficacy of the Preſſure, which makes it aſcend, and its own Weight, make

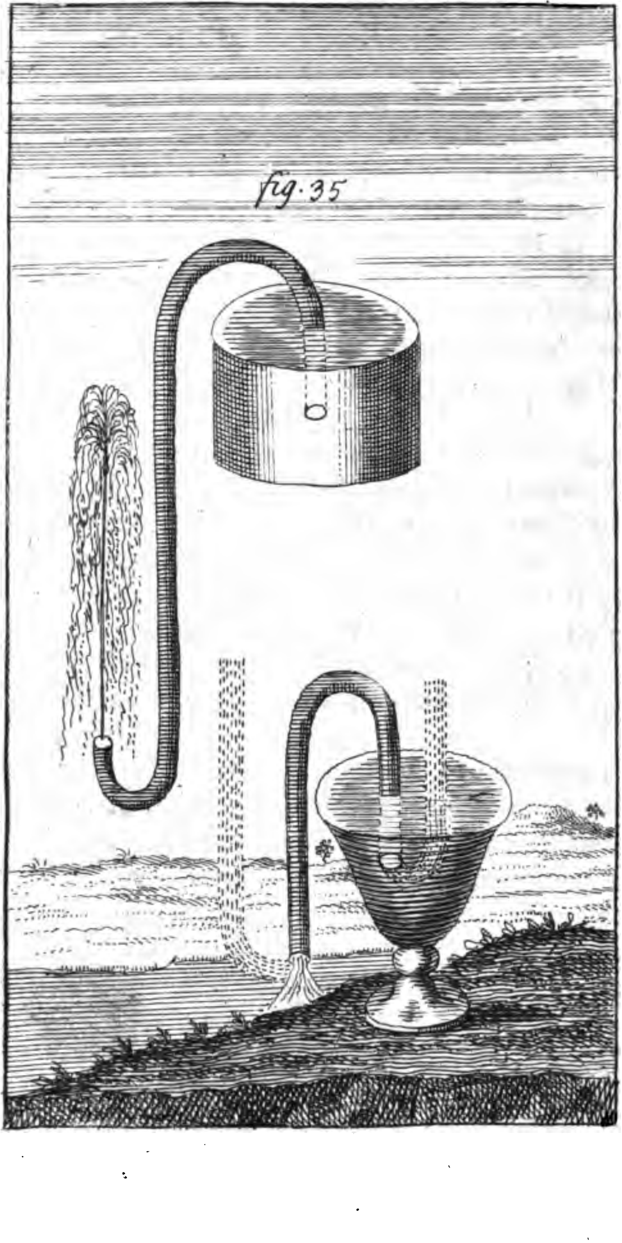

fig. 35

make it deſcend and flow through the longer one.

Eud. Thus the Syphon, ſet a going in the free Air, lets the Water run out more ſlowly in an Air-Pump, in Proportion as you pump out the Air; and when the Air fails, the Syphon ſtops[a]. But ſince the Column of Air, which anſwers to the End of the longeſt Branch, is longer and heavier than the Column which makes the Water at firſt aſcend, why does it not make it to aſcend again, or at leaſt detain it ſuſpended?

Ariſt. The Column of Air, which anſwers to the End of the longeſt Branch, is longer: But it has more Liquor to ſuſtain; and this Exceſs of Liquor ſurpaſſes the Exceſs of the longer Column, in Gravity: Therefore it muſt give Place, and permit the Water to flow. By the ſame Reaſon, the Water will not aſcend, if you plunge into it only the End of the longer Branch.

Eud. Nevertheleſs the capillary or very minute Syphon does not ceaſe to play in the *Vacuum*[b], and Pieces of Cloth, eſpecially when the Cloth is wetted before the Experiment, are full of imperceptible Pipes, which begin to play in the *Vacuum*, and make Liquors to paſs from one Veſſel into another[c].

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[a] Hiſt. del'Acad. an. 1714. p. 85.

[b] Hiſt. de l'Acad. 1714. p. 86. Mem. p. 336.

[c] Mem. de l'Acad. p. 339.

Ariſt. The Beginning or Continuance of this Diverſion ſeems a little contrary to the Hypotheſis of the Air's Gravity.

Eud. Nothing in the Main is more conformable to it; and in Order to conceive it, let us try to diſcover firſt why Liquor aſcends, and is ſuſtained above its Level in the capillary Tube, *Fig.* 36. Is it becauſe the external Air bears it up, and the Air which deſcends into the Tube does not act freely upon it, ſo as to thruſt it back, by Reaſon of the Smallneſs of the Space? Some able Philoſophers have been of this Opinion: But, 1. The Air, which finds free Acceſs into the Barometer through the Hole which is made in the Bladder that cloſes up the ſuperior End, ought to find free Acceſs into a Tube, whoſe Diameter is much larger notwithſtanding its Smallneſs, and to drive downward the Liquor with as much Force as it is puſhed upward. 2. Under the Receiver that is void of Air, the Liquor is equally elevated [d]. The ſame Elevation ſubſiſts, and is likewiſe ſomewhat increaſed [e], becauſe the Air contained in the Liquor extends it ſtill more by the Exceſs of its Dilatation.

What is it then which cauſes the Elevation of a Column of Liquor in a capillary Pipe above its Level? The mutual Adheſion of the Parts of the Liquor, and the Adheſion of the

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[d] Mem. de l'Acad. p. 345.

[e] Mem. de l'Acad. 1705. p. 245.

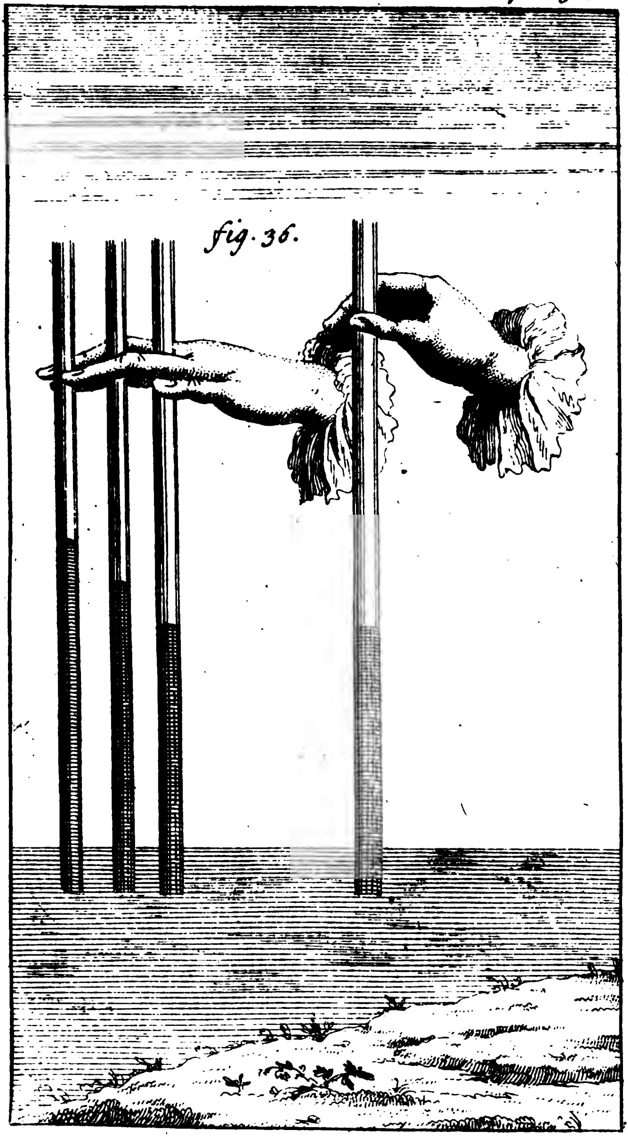

fig. 36.

liquid Column to the internal Surface of the ſmall Pipe; the Spring of the Air contained in the elevated Column, the Viſcoſity of its Parts, or the Facility which their Homogeneity and Texture afford them of being united to one another; and very probably an Atmoſphere, or *Vortex* of ſubtile Matter which circulates round about Bodies, at leaſt about the greateſt Part of them.

In ſhort, 1. The Particles of Water adhere to one another; otherwiſe, in the Time of Dew we ſhould not ſee ſo many Drops of Water ſuſpended upon the Leaves of Plants; the Particles being ſeparated by their Gravity would not compoſe ſo many Drops; neither would two Drops of Water be united again into one, as they are, in their firſt Contact.

2. The Particles of Water ſtick to Glaſs; and the mutual Adheſion of the Particles of Water, as *M. Petit* has remarked[f], is leſs ſtrong than their Adheſion to the Glaſs. For if one wet a clean Glaſs, and ſhake it, many Particles or Surfaces of Water are looſed from one another, while ſtill the whole Surface of the wetted Glaſs remains covered over with Water.

3. The Adheſion of Liquor to the Sides of a capillary Pipe is ſo much the greater, becauſe the Column of Liquor being more fine, touches

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[f] Mem. de l'Acad. 1724. p. 101.

them in a larger Surface with Reſpect to its Maſs.

4. The Adheſion to the Sides of the Tube diminiſhes the relative Gravity of the adhering Column, ſince it hinders the Particles of this Column from ponderating as freely upon the Bottom of the Veſſel, as the Columns ſurrounding it. The Column being diminiſhed in Weight yields to the Spring of the Air which it contains in its Interſtices, and to the Neighbouring Columns, and aſcends until it be in an *Æquilibrium* with them by the Exceſs of its Height.

In a Word, take away the Adheſion and you hinder or diminiſh the Elevation. If one cover the inſide of the Tube with a Lay of very thin Tallow, the Water does not paſs the Level of the other Columns; if it be not covered as far as the Level, the Water aſcends above it to its uſual Point. Cover preciſely one Side, and the Water does not paſs the Level on that Side, but on the other.

The Air contained in the Column which is elevated, finding itſelf relieved by the Adheſion of the ſuperior Parts, bears them up by dilating itſelf, and carries thoſe above the Level with it, from which it cannot wholly diſengage itſelf. The Viſcoſity, Texture, and Homogeneouſneſs of the Parts is the Cauſe why they are united, and ſuſtain one another, whenever they can touch; touching one another in a larger Surface, they leave the leſs Fluid capable of oppoſing their Union.

Before the Experiment, wet the inſide of the Pipe, the Water aſcends the more. It aſcends more or leſs in Proportion to the Texture of its Parts; their Homogeneity its Adheſion to the Parts of the Glaſs, and the internal Air. Hence Water ſometimes aſcends three or four Inches above its Level, while lighter Liquors are elevated much leſs. It aſcends higher in Tubes of a ſmaller Diameter, in which the Columns are more ſupported, having a larger Surface in Regard of their Maſs. The Water alſo aſcends higher in Tubes, which are more plunged into Water; becauſe a greater Part of the elevated Column is ſuſtained by an heavier Column, compoſed of Air and Water; a Caſe which cannot be explained by the Inequality of the Preſſure of the external Air.

Moreover it is very probable, as *M. de Mairan* conjectures[h], that the Magnetic Virtue of Bodies does not only reſpect the Loadſtone, Iron, and ſome other electric Bodies, but the moſt Part of Bodies, after a Manner more or leſs perceptible. If they have their Atmoſphere or *Vortex* of ſubtile Matter, which flows from their Pores, thoſe which will allow Acceſs to the ſame Matter, and whoſe Vortices

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[g] Mem. de l'Acad. 1705. p. 245. [h] Hiſt. de l'Acad. 1724. p. 13.

will unite into one common *Vortex*, will attract one another, or being placed againſt one another, they will immediately join and ſtick together. Other Bodies by a contrary Reaſon will repel one another, or not join immediately, nor ſtick together. Hence Water wets Glaſs, but Mercury does not. Hence two Drops of Water are confounded with one another, whenever they approach, or in their firſt Contact; the intermediate Air being expelled by the ſubtile Matter, which paſſes from the one Drop into the other, runs off; and there is no more *Æquilibrium*.

The expell'd Air flows back, and being joined with the Air behind it, is ſtronger than the intermediate ſubtile Matter, which paſſes freely through the Drops of Water; it puſhes and unites them into one. Hence Water aſcends more ſwiftly and higher in the capillary Pipes, being wet. Hence, in a Word, Mercury does not aſcend above the Level in capillary communicating Tubes, having no Coheſion with the Glaſs; and it alſo remains below the Level, becauſe in Order to paſs from the larger Tube into the ſmaller, and to aſcend in it, it is divided with much greater Difficulty than Water. Perhaps alſo becauſe an Atmoſphere of ſubtile Matter, which comes out of the ſmall Tube, finding in the capillary Column of Mercury a larger Surface in Proportion to its Maſs, detaches it more, and gives it more Freedom to deſcend, than the Mercury of the larger Tube had.

Ariſt. I now ſufficiently underſtand the playing of the Syphon in a *Vacuum.* Three Principles independent upon the preſent Action of the Air's Gravity make it play; the Adheſion of the Column, which anſwers to the Syphon, and renders it lighter than the ſurrounding Columns; the Spring of the Air contained in this Column, and the Homogeneouſneſs of its Parts amongſt themſelves, and with thoſe of the Glaſs. Theſe Principles cauſe the Elevation of the Liquor in the Syphon as far as the Curvature in the firſt Branch, as in the capillary Tube; and the Weight of the elevated Column, ſeconding the internal Air and the Preſſure of the neighbouring and victorious Columns, makes it fall through the ſecond Branch.

Eud. But why do we ſometimes ſee very ſmall Syphons ſtop in *Vacuo*[i]?

Ariſt. They ſtop, when groſs Bubbles of dilated Air happening entirely to cut the ſmall Streams of Liquor, hinder their Parts from joining and making a Weight capable of dragging the liquid Column out of the Syphon.

Eud. Theſe ſmall Syphons, which ſtop ſometimes in a *Vacuum*, begin again to run of themſelves whenever they are replaced in the free Air[k].

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[i] Mem. de l'Acad. 1722. p. 336.

Ariſt. Whenever they are reſtored to the free Air, the internal Air, whoſe exceſſive Dilation hindered the flowing of the Liquor, is contracted; the ſeparated Drops are united again; being united, they drag one another through the ſecond Branch, and make a Weight capable of overcoming the Reſiſtance; and the Syphon runs again as long as it is wet.

Eud. Liquors are diffuſed in Stuffs, becauſe they are full of capillary Pipes, of ſmall Syphons. The Knowledge of the Mechaniſm of theſe ſmall Syphons leads me to underſtand a very curious Experiment. I ſoak ſeparately two Slips of whited brown Paper, the one in Wine, and the other in Oil. Then I mix together the Oil and Wine as well as poſſible.— In theſe Liquors being mixed, I dip one of the Ends of each Slip of whited brown Paper.— The other, which is the longer, comes out paſſing over the Brim of the Veſſel. — You ſee the Wine aſcend and come out of the Veſſel by the Filtre imbibed with Wine, and the Oil by the Filtre imbibed with Oil; each only attracting that Species of Liquor, with which it is impregnated.

Ariſt. Oil and Wine are heterogeneous Bodies, whoſe different Texture hinders their Particles from uniting together, and from touching one another immediately and near enough to drive away the Fluid which may repel them. Perhaps alſo they have different Atmoſpheres which repel them. Hence, when the Wine encounters the Slips impregnated with Oil, it is repelled inſtead of finding any Hold, and freely communicating to the Oil that Preſſure which it receives from the lateral Columns, and the Spring of the internal Air. The Oil has the ſame Fate, when it ſtrikes againſt the Slip impregnated with Wine. But does the Wine encounter the Filtre that has imbibed the Wine? The homogeneous Parts of the Wine touch one another immediately, are united, and faſtened together, without leaving between them any Fluid which might oppoſe their Union; the inferior Parts being puſhed upward by the neighbouring Columns of Wine, and by the Spring of the internal Air, as in the capillary Syphons freely puſh the ſuperior Parts as far as the Curvature; and at laſt hurrying one another along by their Weight, they deſcend through the longer End; by the ſame Reaſon Oil runs through the Filtre impregnated with Oil. Thus the Filtration ſeparates two Species of Liquors.

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[k] Hiſt. de l'Acad. 1714. p. 85.

Eud. What has been hitherto ſaid, *Ariſtus*, in our various Converſations may ſerve to make us comprehend what concerns Fire.

CONVERSATION XXVI.

Upon Fire *.

Ariſt. IT is cold, and I am glad to meet with you, *Eudoxus*, before a good Fire. But I think I ſhould find ſtill much more Pleaſure in warming my ſelf, as you do, like

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* As to the Nature of Fire, there is a great Diverſity of Opinions among the modern Philoſophers, ſome contending that it is formed ſuch originally by the Creator himſelf, at the Beginning of Things; others that it is mechanically producible from other Bodies, by inducing ſome Alteration in the Particles thereof, the former is maintained by *Hamberg*, *Boerhave*, the younger *Lemery*, and *S'Graveſande*; the latter is chiefly ſupported by the *Engliſh*.

It would be too tedious to make Quotations out of each of theſe Authors, therefore we ſhall content our ſelves with but two or three on each Side of the Queſtion.

1. M. *Homberg*, in his *Eſſai du ſouffre Principe*, holds, “That “the chymical Principle or Element Sulphur, which is ſuppoſed “one of the ſimple, primary, pre-exiſtent Ingredients of all na“tural Bodies, is real Fire; and conſequently that Fire is coeval “with Body”. Mem de l'Acad. An. 1705.

Dr. *S'Graveſande* goes much on the ſame Principle: “Fire, “according to him, enters the Compoſition of all Bodies, is “contained in all Bodies; and may be ſeparated, or procured “from all Bodies, by rubbing them againſt each other, and thus “putting their Fire in Motion. But Fire, he adds, is by no “Means generated by ſuch Motion”. *Elem. Phyſ.*

Again, “Fire, ſays the ſame Author, naturally unites itſelf “with Bodies; And hence it is that a Body brought near to the “Fire grows *hot*; in which Caſe it alſo expands or ſwells; which

“Expanſion

like a Philoſopher, and if I knew the Nature of Fire, what produces it, what maintains it, and how it is extinguiſhed.

Eud.

" Expanſion is not only obſerved in very ſolid Bodies, but in " thoſe whoſe Parts do not cohere; in which Caſe they likewiſe " acquire a great Degree of Elaſticity, as is obſerved in Air and " Vapours". *Ibid.*

On the other Hand: " In the Production of Heat, ſays Mr. " *Boyle*, there appears nothing on the Part either of the Agent " or Patient, but Motion, and its natural Effects. When a " Smith briſkly hammers a ſmall Piece of Iron, the Metal thereby " becomes exceedingly hot; yet there is nothing to make it " ſo, except the forcible Motion of the Hammer, impreſſing a " vehement, and variouſly determined Agitation, on the ſmall " Parts of the Iron, which being a cold Body before, grows, by " that ſuper-induced Commotion of its ſmall Parts, *hot:* Firſt in " a more looſe Acceptation of the Word; with Regard to ſome " other Bodies, compared with which it was cold before: Then " ſenſibly hot; becauſe this Agitation ſurpaſſes that of the Parts " of our Fingers: And in this Inſtance, oftentimes, the Hammer " and Anvil continue cold, after the Operation; which ſhews, " that the Heat acquired by the Iron, was not communicated by " either of thoſe Implements, as heat; but produced in it by a " Motion, great enough ſtrongly to agitate the Parts of ſo ſmall a " Body as the Piece of Iron, without being able to have the like " Effect upon ſo much greater Maſſes of Metal, as the Hammer " and the Anvil. Tho' if the Percuſſions were often, and briſkly " renewed, and the Hammer were ſmall, this alſo might be " heated. Whence it is not neceſſary, that a Body itſelf ſhould " be hot to give Heat.

" If a large Nail be driven by a Hammer into a Plank of " Wood, it will receive ſeveral Strokes on its Head, e'er it grow " hot; but when it is once driven to the Head, a few Strokes " ſuffice to give it a conſiderable Heat: For while at every " Blow of the Hammer, the Nail enters farther into the " Wood, the Motion produced is chiefly progreſſive, and is of " the whole Nail, tending one Way; but when the Motion " ceaſes, the Impulſe given by the Stroke, being unable to drive " the Nail farther on, or break it, muſt be ſpent in making a various, " vehement, and inteſtine Commotion of the Parts among

" themſelves;

Eud. Here is my Sentiment upon that Head. 1. What is Fire? It is a Body compoſed of ſubtile Matter and groſſer Particles, agitated by the ſubtile Matter with a rapid and univerſal Motion,

“ themſelves; wherein the Nature of Heat conſiſts. *Mech. Produc. of Heat and Cold.*

Agreeable to this is the Opinion of Sir *Iſ. Newton*, who conceives that “ groſs Bodies may be converted into Light by the Agitation of their Particles; and Light again, into groſs Bodies, by being fixed therein.

Again, “ Fire, according to him, is only a Body much ignited, *i. e.* heated hot, as to emit Light copiouſly: What elſe, ſays he, is a red-hot Iron than Fire? And what elſe is a burning Coal than red-hot Wood? Or Flame itſelf than red-hot Smoak? 'Tis certain that Flame is only the volatile Part of the Fuel heated red-hot, *i. e.* ſo hot as to ſhine: And hence only ſuch Bodies as are volatile, *i. e.* ſuch as emit a copious Fume, will flame; nor will they flame longer than they have Fume to burn. In diſtilling hot Spirits, if the Head of the Still be taken off, the aſcending Vapors will catch Fire from a Candle, and turn into Flame. So ſeveral Bodies much heated by Motion, Attrition, Fermentation, or the like, will emit lucid Fumes, which, if they be copious enough, and the Heat ſufficiently great, will be Flame; and the Reaſon why fuſed Metals do not flame, is the Smallneſs of their Fume; for that Speltre, which fumes more copiouſly, does likewiſe flame. Add that all flaming Bodies, as Oil, Tallow, Wax, Wood, Pitch, Sulphur, *&c.* by flaming, waſte and vaniſh into burning Smoak.

“ And do not all fixed Bodies, when heated beyond a certain Degree, emit Light and ſhine; and is not this Emiſſion performed by the vibrating Motion of their Parts? And do not all Bodies, which abound with terreſtrial and ſulphureous Parts, emit Light as often as thoſe Parts are ſufficiently agitated, whether that Agitation be made by external Fire, or by Friction or Percuſſion, or Putrefaction, or by any vital Motion, or any other Cauſe? As for Inſtance, Sea-Water in a raging Storm, Quickſilver agitated in *Vacuo*, the Back of a Cat, or Neck of a Horſe obliquely ſtruck or rubbed in a dark Place, Wood, Fleſh, and Fiſh while they putrify, Vapors from putrifying

Motion, with a Motion upon their Center, and with Vibration. 1. Fire is a Body; one ſees and touches it. 2. This Body is compounded of ſubtile Matter; for in a Word, it penetrates the hardeſt and moſt ſolid Bodies. 3. It contains more groſs Parts, ſince it diſſolves and reduces the moſt maſſy Bodies to Powder. Could the ſubtile Matter alone produce ſo ſenſible Effects, finding free Paſſages through the ſtraiteſt Pores? 4. Thoſe groſs Parts are agitated; they do not move without being moved. 5. Their Motion is a rapid Motion; the imperceptible Parts of themſelves, each one in Particular, would not make ſo great Havock if

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“ trifying Waters, uſually called *Ignes fatui*, Stacks of moiſt Hay
“ or Corn, Glow-worms, Amber and Diamonds by rubbing;
“ Scrapings of Steel, ſtruck off with a Flint. Iron hammered
“ very nimbly, till it become ſo hot as to kindle Sulphur thrown
“ upon it; the Axle Trees of Chariots taking Fire by the rapid
“ Rotations of the Wheels; and ſome Liquors mixed with one
“ another, whoſe Particles come together with an Impetus, as
“ Oil of Vitriol diſtilled from its Weight of Nitre, and then
“ mixed with twice its Weight of Oil of Aniſeeds, *&c.*

“ Are not groſs Bodies and light convertible into one another,
“ and may not Bodies receive much of their Activity from the
“ Particles of Light, which enter their Compoſition? For all
“ fixed Bodies being heated, emit Light ſo long as they conti-
“ nue ſufficiently hot, and Light mutually ſtops in Bodies, as of-
“ ten as its Rays ſtrike upon their Parts. I know no Body leſs
“ apt to ſhine than Water, and yet Water by frequent Diſtillati-
“ ons changes into fixed Earth, as Mr. *Boyle* has tried; and then
“ this Earth being enabled to endure a ſufficient Heat, ſhines by
“ Heat like other Bodies”. *Opticks.*

As to *Boerhave*'s Experiments for the Proof of elementary Fire; we muſt wait till he ſhall oblige the World with his Chymiſtry: In the mean Time whoever has a Mind to ſee more upon this Head, may conſult Dr. *Shaw's new Method of Chymiſtry.*

the Rapidity of their Motion did not yield any Aſſiſtance to their Smallneſs. 6. It is an univerſal Motion. Draw near the Fire on which Side you pleaſe, you will ſtill feel its Action. 7. A Motion of Particles upon their Center; for thoſe Parts, at leaſt moſt of them, having their Extremities unequal and differently moved, muſt neceſſarily turn about, at leaſt moſt of them, upon their Center. 8. Finally, this Motion is a vibratory Motion, by which the Parts go and return. When turning about upon their Center they preſent the Point to the Matter which ſurrounds them, they puſh it; when they preſent the Sides, they ſuffer it to return upon them with Impetuoſity. Hence thoſe Parts come and return, ſometimes victorious, and ſometimes vanquiſhed. Here is the Idea of terreſtrial Fire; an Idea which agrees to the Sun itſelf, ſince it enlightens, warms, ſparkles and ſhines like terreſtrial Fire.

There is a ſort of Fire more compact; ſuch is a burning Coal; and a Fire more ſubtile and light; that is Flame. The firſt is a Fire, whoſe Parts are not entirely ſeparated. The ſecond is a Fire, whoſe Parts being wholly ſeparated, are darted out freely on all Sides, The burning Coal is a more violent Fire than Flame, becauſe it contains a greater Quantity of groſs Parts, which conſpire to the ſame Effect. The Force of Motion proceeds from the Maſs as well as from the Velocity; and if there is ſome Exceſs of Velocity in the Parts of the Flame, the Exceſs of Maſs ſurmounts it in the Parts of the Coal.

By the ſame Reaſon, Flame is ſometimes ſtronger, and ſometimes weaker. It is ſtronger, when it contains a greater Number of groſs Parts, as the Flame of green Wood; and weaker, when the Parts, which compoſe it, are more minute and fine, as the Flame of Spirit of Wine. Why does the Flame of Spirit of Wine flow upon Paper, without burning it? I drench my Fingers in this Liquor: I bring them near a Wax-Candle. You ſee them on Fire. This Fire is ſcarcely perceived, becauſe the Particles of the inflamed Liquor are ſo fine, and their Forces ſo little united, by Reaſon of their Separation and univerſal Efforts, that, notwithſtanding their Velocity, they have not Force enough to divide the groſs Parts of the Paper and Hand.

2. What produces Fire? All Bodies whoſe Motion ſhakes, ſeparates, and diſengages the imperceptible but ramous Parts of a combuſtible Body; ſo that thoſe Parts being diſengaged and ſeparated may follow the rapid Motion of the ſubtile Matter, which ſlides betwixt them, and ſurrounds them. By the Definition of Fire, it conſiſts in the Action of theſe two Species of Matter, one of which obeys the impetuous Motion of the other. Hence, Fire, the Friction of certain hard Bodies, Moiſture, and Water itſelf produces Fire.

Fire produces Fire in three Sorts of Bodies; in ſoft Bodies, as Wax; in liquid Bodies, as Oil and Spirit of Wine; and in hard Bodies, as Wood. Fire, I ſay, produces Fire in theſe different Species of Bodies, by ſeparating their Parts by its Irruption into their Interſtices, and joining its Action to the Efficacy of the Spring of the internal Air, and to the Motion of the ſubtile Matter, which encompaſſes the imperceptible Parts of thoſe Bodies. Do the Particles of an igneous Body, for Example, happen to ſtrike againſt Wood? They ſhake the Parts of the Wood by their Agitation, diſengage, detach, and put them into a Condition of complying with the Motion of the ſubtile Matter, give Entrance to ſome new Matter of this Species, and ſecond the Spring of the internal Air which plays, and by ſetting itſelf at Liberty breaks Thouſands of ſmall *Cellules*, which retained it as impriſoned; thus the Parts of the Wood are in a rapid and confuſed Motion, and the Wood is ſuddenly changed into Fire.

Dry Wood catches Fire ſooner than green; becauſe the Fire, which eaſily inſinuates itſelf into the Pores of the dry Wood, in which it finds nothing but Air, can ſcarcely get into the Interſtices of the green Wood, where the Water does not afford it ſo free an Acceſs. But why does Wood that has floated kindle more eaſily than new Wood? Becauſe in Float-wood the Action of the Sulphurs, whoſe imperceptible Parts are ſurrounded with much ſubtile Matter, and which at firſt take Fire, is no longer moderated nor bridled, if I may ſo ſay, by the Salts, whoſe Solidity retards the Mechaniſm of the Sulphurs in the new Wood. In ſhort, Float-wood loſes its Salts by the Lye which is made of them in the Water; whence it comes to paſs that the Aſhes of Float-wood are not proper for whitening Linnen.

If the igneous Parts are wholly ſeparated, and have Force enough to repel the ſurrounding Fluid to a certain Diſtance, it is a Flame which iſſues out of the Boſom of the Wood. Are they not entirely ſeparated, or have they not Force enough to diſſipate themſelves by removing the Fluid which encompaſſes them? It is a burning Coal. Strike the Steel: Some ſmall Particles of Steel or Flint, which were ſurrounded with ſubtile Matter, and contracted Air, are ſuddenly diſengaged and detached by the united Forces of the Hand, the Spring of the Air, and the ſubtile Matter; and turning round with Rapidity upon their Center in the Middle of this Matter, they fly out and make Sparkles ſhine to the Eye, like thoſe which are darted out from a Flame, in which you let fall Filings of Iron. Do you doubt whether the Sparkles, which ſeem to leap out from the Boſom of the Flint, can be any Thing elſe but ſmall melted Particles of Steel, or of Flint itſelf, violently agitated? Receive them upon ſome white Paper; and with a Microſcope you will ſee the Truth. By the ſame Principle Wood of *Bambou* (that is an *Indian* Wood) gives Fire, like flint Stones, when they rub two Pieces of this Wood againſt one another *.

If one ſhut up Hay while moiſt, the terreſtrial Spirits, with which it is ſtill impregnated, diſengaging themſelves more and more by the Favour of the Spring of the internal Air, and the Stroke of the ſubtile Matter, come at laſt to ſwim freely in this Matter; and being hurried along by their rapid Motion they break, thruſt, and diſſipate all the ſmall Parts of the Hay; thus Hay is ſet on Fire.

Pour Water upon Lime: The Lime heats and inflames. Why? When the Lime is made, the Heat breaks the Fibres of the Stones in Calcination, works out new Pores, and enlarges the former. Theſe Pores, theſe Interſtices are filled with ſubtile Matter and igneous Bodies. When the Lime begins to cool again, the external Air penetrates into very many of the Pores, and condenſes in them by the ſinking down of the Parts upon one another. The Air, the ſubtile Matter, and the Particles of Fire, ſtrive to diſſolve thoſe Parts: Had they ſome more Degrees of Force, the Solution would happen. Pour on Water: The Matter of the Lime being extremely dried up, receives the Water, which is poured on it, with a Sort of Greedineſs. The Agitation of the Water;

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* Journ. des Sçav. p. 268. 1686. 2. *Sept.*

which penetrates it impetuouſly, diſengages the Parts of the Fire, renders them victorious, and furniſhes neceſſary Degrees of Force. The Parts of the Lime being forced to yield, are wholly ſeparated: Being ſeparated, they are darted out on all Sides without being entirely diſſipated, becauſe the external Air, which ſurrounds them, does likewiſe retain them; and this is an Ebullition, a ſenſible Heat, a Flame, which ſhines to the Eye.

In vain would you attempt to kindle a combuſtible Body in a Place void of Air. The burning Glaſs does not kindle Sulphur itſelf in an Air-Pump, out of which one has pumped the Air; becauſe the Parts of the Sulphur being violently agitated, as they are not retained by the external Air, are too much diſſipated to make a ſenſible Flame. Nevertheleſs if you add Salt-petre to the Sulphur, the Sulphur inflames, becauſe the Salt-petre hinders the exceſſive Diſſipation of the Sulphur.

Ariſt. Thus the Fire is kindled; the Buſineſs now is how to maintain it; its Parts being agitated endeavour to diſſipate, and they paſs away in Smoak, when they have loſt a great deal of their Agitation. What is it that ſupports the Fire?

Eud. All Bodies which furniſh it with Fuel, in Order to repair the Loſs which it has made, as Wood, or which hinders the Diſſipation of its Parts, as Aſhes and the external Air. Fire is principally nouriſhed with groſs Bodies, which contain Plenty of Salts, Salt-petre, and Sulphur. Has Wood loſt its Salts by floating upon the Waters? The Fire of it is the leſs ardent, although the Wood burns with great Velocity on that Account; and ſince Fire, when it is ardent, penetrates the hardeſt Bodies, it muſt have round or pointed Particles, as thoſe of Salt-petre. The more Sulphur combuſtible Bodies have, the more eaſily they kindle. Are they without ſulphureous Particles, as Water and Aſhes, they ſcarcely burn. A kindled Coal does not fail to be preſerved under Aſhes without new Fuel; becauſe the Aſhes hinder its Parts from being wholly detached and diſſipated.

By the ſame Reaſon, the Air contributes to the Preſervation of the Fire, which it ſurrounds. Why is Fire hotter in Winter? Becauſe being ſurrounded with a thicker Air, it is leſs diſſipated. A Wax-Candle is quickly extinguiſhed in an Air-pump, in which the Air no longer oppoſes the Diſſipation of the Flame.

The Flame of the Wax-Candle owes its Preſervation to the Preſſure of the free Air. The free Air by its Weight and Spring preſſes the ſmall Parts of Wax divided by the Heat of the Flame; theſe Parts being compreſſed aſcend by the Wick, as through an Infinity of capillary Pipes, into the *Focus*, where the Reſiſtance is leaſt, by Reaſon of the ſucceſſive and continual Departure of a Quantity of Particles, which paſs into Flame: Thus Wax feeds the Flame.

The Flame being violently agitated ſtrives to diſſipate itſelf; but the lateral Air ſtays its Efforts. The Weight of this Air prevails againſt that of the Flame; and the Flame being lighter, aſcends. In its Elevation, its Particles, in Proportion as they are farther diſtant from the *Focus*, and leſs perpendicular to it, give more of their Force to the Air, and their loſt Forces are leſs repaired. Hence the lateral Parts of the Flame are diſſipated, paſs into Smoak, diſappear, and the Flame terminates in a Pyramid; a Figure which the Flame takes ſo much the more eaſily, becauſe this Figure is fitter to divide the Air, ſince it communicates leſs Motion to the ſuperior Air. The Flame of a Wax-Candle ſeems ſometimes to bound, augment and diminiſh in an Inſtant; becauſe of the Tremulation of the Air, or becauſe it does not always equally receive Nouriſhment.

What I have ſaid of the Wax-Candle, one may ſay of the Lamp. Is the Lamp upon the Point of being extinguiſhed for Want of Oil? The Flame is elevated, and its Light is thereby the more bright. That is becauſe the Air, which detaches this weak Flame, bears it up by taking its Place. The Effort which bears up the Flame, communicates an Agitation to its languiſhing Particles, which animates them, and gives them that momentary Vivacity, to which they compare thoſe unexpected Moments of Vigour, which makes us hope for the Cure of a ſick Perſon, when he is juſt bordering upon the Point of Death.

Ariſt. But finally, how is the Fire extinguiſhed? The Queſtion is to extinguiſh it like a Philoſopher.

Eud. The Fire is extinguiſhed through want of Nouriſhment, or by the Exceſs of a too violent blowing, or by the Action of Liquors which are not ſulphureous; ſometimes by being too compact, and ſometimes by not being ſufficiently compacted; and at other Times becauſe moſt of theſe Reaſons happen to be united. 1. Fire is extinguiſhed for want of Fuel, becauſe the agitated Parts loſe their Motion, and go off in Smoak, without others coming to ſupply their Place with this rapid Agitation, in which Fire conſiſts. 2. Fire is extinguiſhed by the Exceſs of too violent blowing; becauſe exceſſive Blowing detaches the Flame from the combuſtible Body, which furniſhed it with Fuel. 3. Fire is extinguiſhed by the Action of Liquors, of Water for Example; becauſe this ſort of Liquor, by running into the Interſtices of lighted Bodies, ſtay their Particles, whoſe Motion they aſſume, which diſſipates them into Smoak. Nevertheleſs when the Fire is violent, Water only ſerves ſometimes to render it more ardent, becauſe it only hinders the Diſſipation of the igneous Corpuſcles, and furniſhes Matter to a rapid Fire. Hence, the Water wherewith Smiths beſprinkle their burning Coal, only ſerves to inflame it ſtill more. 4. Fire is extinguiſhed in a Place too much confined; becauſe the Corpuſcles of Fire loſe their Agitation in it, without being able to ſeparate themſelves. Thus, when one can get all the Vents of Caverns ſtopped, one effectually ſmothers Fire in them. If Fire lays hold on the Chimney, a wet Cloth, which you extend before it, is capable of preventing Combuſtion; Why? The external Air, which correſponds to the Vent of the Chimney, not being able to circulate, becauſe the wet Cloth leaves no Acceſs into the Chimney, hinders the kindled Soot from extending itſelf, from communicating its Motion, and from iſſuing out; it ſmothers it; or elſe the kindled Matter is detached, but being too weighty to ſupport itſelf in the Air, becauſe it is too much contracted to dilate itſelf, and being only ſuſtained by an Air ſtrongly rarified, it falls, and is extinguiſhed after having cauſed ſome vain Alarms. 5. Pump out the Air from the Air-pump, whenever the Flame in it is no longer compreſſed by the Air to a certain Degree, it is diſſipated and diſappears.

If what is ſaid of the Salamanders is as true, as it is probable, they extinguiſh Fire after a ſingular Manner[1]. *Steno*, a famous Anatomiſt, affirms in a Letter written by him, that the Chevalier *Corvini* told him, that having thrown into the Fire a Salamander brought from the *Indies*, it ſwelled at firſt, and vomited ſome liquid Matter with which it extinguiſhed the Coals next to it, that it guarded itſelf from the Violence of the Fire during the Space of two Hours, extinguiſhing the Coals continually after the ſame Manner, when they were kindled again, and that it was ſtill alive nine Months after.

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[1] Journ. des Sçav. 1667. 25. Avr. p. 94.

Whatever be in that, the Secret which the *Germans* have invented for extinguiſhing of Fire, unites together, and ſets a working at the ſame Time almoſt all the Methods of extinguiſhing it [m]. The Experiment of it has been ſeen in a Cave, and in a Sort of Barrack of Plank, built in the Fore-Court of the Invalids. The Barrack was built after the Faſhion of *Foires St. Germain*, upon a ſquare Plain, each Side whereof was about 18 Foot. Its Height was about 10 Foot, taking it from the Level of the Ground, to the Beginning of the Roof; which was elevated five Foot. The Flame ſpread abroad on all Sides in the Cave, and in this Sort of Houſe, was ſmothered all at once. Here is the Secret equally ſimple and ingenious.

In the Middle of a Barrel full of Water, about 22 Inches in Height, and 13 Inches in Diameter, there is a cylindrical Box of Tin, almoſt four Inches in Diameter, and which can contain about two Pound of Gunpowder.

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[m] Mem. de l'Acad. 1722. p. 143.

The Box is terminated by a long Neck, which paſſes through one of the Bottoms of the Barrel. A Fuſee contained in this long Neck can convey the Fire from without inwardly. Should one have a Mind to make Uſe of this Barrel thus prepared, you ſet Fire to the Fuſee, and thruſt forward the Barrel into the Fire as much as poſſible. In a ſhort Time the Box and Barrel burſt; the Combuſtion ceaſes, if the Fire be not very vehement; at leaſt the Flame is extinguiſhed ſuddenly, and the Combuſtion becomes acceſſible. Whence proceeds this ſudden Extinction?

Ariſt. The Powder being kindled, and finding Reſiſtance in the Box, Water, and Barrel, has Leiſure to be inflamed and act almoſt at the ſame Time. Being inflamed, it is dilated prodigiouſly, acts univerſally, breaks the Box, ſtaves the Barrel, makes the Hoops fly off, and ſhoots out on all Sides an Infinity of ſmall Water Spouts. The neighbouring Air, being equally compreſſed on all Sides at firſt by the Rarefaction of the Powder, ſtops the Circulation of the external Air from without inwardly, contracts the Flame of the Combuſtion by its Preſſure, detaches it, and makes it quit its Hold, by the Quickneſs and Livelineſs of its Action. The Air iſſues out; what remains, being extremely rarefied, no longer hinders the Flame from diſſipating. The Water ſhot out on all Sides accompliſhes the ſmothering of it; and wetting the whole Surface of the combuſtible Bodies, it renders them inacceſſible to the Flame of the Powder, being weakened by the Exceſs of its Rarefaction. Thus the Fire is extinguiſhed, according to the Rules of Phyſics, by a Secret which unites together, and ſets a working at the ſame Time almoſt all the ordinary Methods of extinguiſhing it. But why does a Firebrand, when extinguiſhed, throw out more Smoak than formerly?

Eud. The Smoak, which proceeds from kindled Bodies, or from ſuch as are extinguiſhed, is a Collection of groſs and ſeparated Parts, but which have not that Rapidity of Motion, which Fire requires; whether it be that they have never acquired it, or that they have loſt it. The extinguiſhed Firebrand throws out more Smoak, becauſe the Particles, which a rapid Motion before diſſipated, are united, having loſt a great deal of their Force, and compoſe all together a Maſs of groſs Parts, which paſs off in Smoak.

Let us now kindle again the extinguiſhed Fire. I bring a lighted Candle near a Candle which one has extinguiſhed, and which ſtill ſmoaks; the Flame goes in Search of it.

Ariſt. The Reaſon is, becauſe the Flame is puſhed with more Force toward the Candle by the external Air, than it is puſhed back by the rarefied Air, which is between it and the Candle.

Eud. This Flame quickly Lights the Candle again.

Ariſt. Becauſe the Flame finds ſtill in the Candle Particles ſtrongly agitated, and which require no more, in Order to be inflamed again, than a light Increaſe of Agitation.

Eud. I think, *Ariſtus*, we know ſufficiently the Nature of Fire, and what produces, maintains, or extinguiſhes it. Would you have us henceforth to ſpeak of different Fires, the Fires which we ſee upon the Surface of the Earth? As for the Fires which one ſometimes ſees ſhining in the Air, we ſhall ſpeak of them among the Meteors.

Ariſt. The Fire, which ſurprizes me moſt, is that of Gunpowder.

Eud. Well, at the firſt Opportunity we ſhall entertain one another with this Powder; I ſhall tell you its Origin.

Ariſt. I ſhall ſpeak of its Compoſition; I have ſeen it made.

Eud. We ſhall next attempt to diſcover whence its Force proceeds, and how the divers Effects of this inflamed Powder are produced.

The Original of Gunpowder, its Compoſition, and its Effects phyſically explained, will make up the Subject of our next Converſation. To Morrow at two of the Clock in the Afternoon I ſhall wait for you in the Garden of the *Arſenal.*

CONVERSATION XXVII.

Upon Gunpowder.

Ariſt. THE Subject which brings us together, *Eudoxus*, has ſomething frightful in it; and all its Uſefulneſs conſiſts in overturning and deſtroying. Nevertheleſs it does not want its own Agreeableneſs. Begin, I pray you, with teaching me the Original of Gunpowder †, as you promiſed.

Eud.

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† The ordinary Account of the Invention of Gunpowder is falſe, it being evident from the Writings of *Roger Bacon*, commonly called *Fryar Bacon*, who flouriſhed about the Year 1226, that Gunpowder was well known to him: “ Thunder and Lightning, he tells us, may be produced by Art, for that Sulphur, Nitre, and Charcoal, which when ſeparate have no ſenſible Effect, when mingled together in a due Proportion, and cloſely confined, yield a horrible Crack. A more preciſe Deſcription of Gunpowder cannot be given in Words; and yet a Jeſuit *Barthol. Schwartz*, ſome Ages after, has had the Glory of the Diſcovery”. *V. Shaw's Chemiſtry.* p. 17.

The Exploſion of Gunpowder is thus explained by Sir *Iſaac Newton*. “ When Gunpowder takes Fire, it goes away into flaming Smoak. For the Charcoal and Sulphur eaſily take Fire, and ſet Fire to the Nitre; and the Spirit of the Nitre being thereby rarified into Vapor, ruſhes out with Exploſion much after the Manner that the Vapor of Water ruſhes out of an *Æolipile*; the Sulphur alſo being volatile is converted into Vapor, and augments the Exploſion. And the acid Vapor of the Sulphur (namely that which diſtils under a Bell into Oil of

“ Sulphur

Eud. To give that for certain which one eſteems only probable, is impoſing on the Credulity of thoſe to whom one ſpeaks. Accordingly, I only offer to you as probable, but as very probable, what I am going to ſay of the Original of Gunpowder. Who firſt found out the Secret of Powder in *Europe?* How did they diſcover it, and in what Time? Who firſt found it, I ſay? It was not a Man, if we believe an Author who wrote an Hundred Years ago, and more. *Polydore Vergil* being aſtoniſhed at the Fire, Noiſe, and fearful Crack cauſed by the Inflammation of Gunpowder, appears at firſt convinced, that *Salmoneus* himſelf could not find out the Art of imitating the Thunderbolt ſo well. In his Aſtoniſhment, he affirms *, that the Devil, that Hell alone could invent a Secret ſo proper for giving the World

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" Sulphur) entring violently into the fixed Body of the Nitre, " ſets looſe the Spirit of the Nitre, and excites a greater Fermen" tation, whereby the Heat is farther augmented, and the fixed " Body of the Nitre is alſo rarified into Fume, and the Exploſi" on is thereby made more vehement and quick. For if Salt of " Tartar be mixed with Gunpowder, and that Mixture be " warmed till it takes Fire, the Exploſion will be more violent " and quick than that of Gunpowder alone, which cannot pro" ceed from any other Cauſe than the Action of the Vapor of " the Gunpowder upon the Salt of Tartar, whereby that Salt is " rarified. The Exploſion of Gunpowder ariſes therefore from " the violent Action whereby all the Mixture being quickly and " vehemently heated, is rarified and converted into Fume and " Vapor: Which Vapor, by the Violence of that Action, be" coming ſo hot as to ſhine, appears in the Form of a Flame". *Opticks*, p. 317.

* Lib. 3. de inv. rerum, Cap. 13.

ſuch ſtrange Phænomena, and for deſtroying Mankind. Notwithſtanding having recovered from his extream Aſtoniſhment, probably after having obſerved that, ſince the Invention of Powder, War ſeems not to be more murdering than it was in the Time of *Charles Martel*, who without either Powder or Gun covered the Fields with Dead; he was very willing to agree to it, that a Man in his Fury might invent both Gunpowder and the Gun itſelf. But at the ſame Time he condemns, plainly and without Ceremony, the Inventor to preſent his Head before the Mouth of the Cannon, waiting, without moving his Foot, for the Effect and Reward of his own Invention. He ordains him, without Mercy, to the Reward of that unhappy *Perillus*, who by the Appointment of *Phalaris*, was firſt burnt in the braſs Bull which he had invented for the Puniſhment of Malefactors; and the Reaſon of ſo ſevere a Sentence, is a Sentence taken out of *Ovid*.

Neque enim lex æquior ulla eſt,
Quàm necis artifices arte perire ſuâ.

For my Part, I cannot believe that the Inventor of Gun-Powder was ſo culpable. For in a Word, he was a Religious, a Monk, a Father of the Order of St. *Francis* †, and a ſkilful Chymiſt. At leaſt a very conſtant Tradition affirmed it, more than a hundred Years ago; it was ſaid in Verſe and in Proſe, and *Pancirollus* * and *du Cange* affirm in their Writings, that they were ſo perſuaded. Now, it is probable that this religious ſolitary Chymiſt hardly meditated in his Retirement the Deſtruction of Mankind.

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† Obſerv. choiſies, *&c.* T. X. à Hall.

In ſhort, how did he diſcover the Secret of Powder? Without ſearching for it. It was neither Penetration of Judgment, nor Malice of Heart, nor Deſire of deſtroying Men, nor the Rage of overturning Walls, or ranſacking Towns, that taught him the Compoſition and Force of Powder. Chance, the Author of moſt Diſcoveries, made this to him. The religious Chymiſt was a Phyſician; and far from deſigning to kill any Body, he was making up ſome Remedies. If by that Means he laboured to make Men periſh, it was unknown to him. In ſurveying his Remedies he had made a Mixture of Sulphur, Salt-petre, and Coal, in a Veſſel. Upon this Mixture he placed a Stone[n]. Then having Occaſion for Light, he ſtruck the Steel. A Sparkle fell upon the Mixture, and the ſolitary Phyſician was much aſtoniſhed to ſee at once his Mixture and Remedies on Fire, the Stone in the Air, and ſhot out with a Crack toward the Cieling. He eaſily underſtood what might be the Force of a Powder compoſed of Grains, wherein Sulphur, Salt-petre, and Coal ſhould be predominant; and this is what they call Gunpowder, becauſe when they knew its Force and Properties, they quickly charged Guns with it, which made Streams of Blood to flow contrary to the Intention of the religious and innocent Inventor.

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* De Tormentis mural.

[n] Du Cange, T. I. 579. Pancirole, de Torm. mur. p. 284.

Nevertheleſs he who invented it was not the firſt that knew how to make Uſe of it. But one of his Brethren, a Chymiſt like himſelf, found out this Uſe equally profitable and fatal. The Invention of Gunpowder is aſcribed to *Roger Bacon* an Engliſhman, and the Art of uſing it to *Bartold* the Black, a *German* [o], both the one and the other probably little converſant in the Buſineſs of War; but learned Chymiſts, who both equally concurred in the Receſſes of their Solitude, to pour out and to ſave humane Blood, perhaps without thinking on it; for ſince the Invention and Uſe of Gunpowder, ſo much the fewer Perſons have periſhed perhaps in Battles, as there is more Noiſe made in them than was made before the Uſe of Fire-Arms.

But in what Time did they find out this Powder and its Uſe, at preſent ſo famous throughout the whole Univerſe? It is difficult preciſely to fix the Epocha of it. But it is probable that it was in the Beginning of the

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[o] Obſerv. choiſ. & Sçav. T. 10. à Hall. Obſerv. 12.

14th Century, and much ſooner than many Authors have believed it. If we have no Monuments before this Time, which make Mention of Gunpowder, and if we have one of the Year 1338, which evidently ſhews that they made Uſe of it in 1338, in the Sieges of Towns, one ought, I think, to refer to the Beginning of the 14th Century both the Invention and Uſe of Powder. This Invention and Uſe well deſerved to find a Place in Hiſtory; and probably ſome Time before they uſed it in attacking Places, they had found out both Powder and the Art of uſing it.

Now, 1. There is no Mention made of Gunpowder in the Monuments previous to the 14th Century; I ſay it at leaſt upon the Teſtimony of *Mirée*, *Polydore Vergil*, and *Mariana*, who aſſures us that before 1343, he had ſeen no Trace of Gunpowder in Hiſtory.

2. We have a Record which proves evidently, that in 1338, they made Uſe of it in Sieges: For in the Chamber of Accompts of *Paris*, in an Accompt of 1338, they ſpeak of Expences made for Powder neceſſary to the Guns, which were before *Puy Guillaume*, a Caſtle in *Auvergne*. Therefore it is probable that the Beginning of the 14th Age ought to be the Epocha of the Invention and Uſe of Gunpowder.

In one Word, a religious Chymiſt having caſually made a Spark of Fire to fall upon a Mixture of Sulphur and Salt-petre, which took Fire, and ſhot up the Stone with which it was covered, found out the Secret of Powder; another religious Chymiſt found out the Uſe of it; both the one and the other are found to have been in the Beginning of the 14th Century. Such is probably the Original of Gunpowder. What is the Compoſition of it?

Ariſt. We ſee every where, *Eudoxus*, what forms the moſt marvellous Mixtures; the Queſtion is only to know how to match them together. But this is exactly the Point of Difficulty, which Chance ſooner ſurmounts than the Efforts of a profound Meditation. They had ſeen in all Ages Salt-petre, Sulphur, and Coal; and yet always before the 14th Century they had probably been ignorant, at leaſt in *Europe*, that Coal, Sulphur, and Salt-petre being beſprinkled with Water, mixed, pounded, bruiſed, beat together in a Mortar, then made to paſs through a Sieve, and divided into Globules, ought to make Powder, which would throw down the Walls of the ſtrongeſt Places, make Warriors, Baſtions and Towers to whirl about in the Air, and in one Inſtant carry Death farther than a Quarter of a League. Now, this Powder, ſo long a Time unknown, and notwithſtanding ſo powerful, this Powder compounded of Salt-petre, Sulphur, and Coal, is Gunpowder.

Upon Caſks, ſuch as we ſee here, bored through in their Baſes, open upward, and filled with the Rubbiſh of old Buildings, with fat and ſaltiſh Earth, and with Earth where

Animals have left what does not paſs into the Subſtance of the Blood, they pour Water, which in filtring detaches by its Weight and Motion, diſſolves and carries along with it into a Veſſel the ſmall Particles of Salt diffuſed in the Earth. Afterward they boil this Water thus charged with Salts. The Water is evaporated by the Heat. After the Evaporation, the Salts which they ſuffer to cool again, are united together in Form of Ice. This Ice, which is formed in Summer as well as Winter, is Salt-petre.

The Salt-petre is thrown into the Mortars of Powder-Mills, with Sulphur. Upon this Maſs of Sulphur and Salt-petre they ſpread pounded Coal, proper for receiving and containing in its open and numerous Pores, made by the Violence of Fire, the Salt-petre and Sulphur united together. They mix five or ſix Parts, ſometimes leſs, of well refined Salt-petre, one Part of Sulphur, and one Part of pulverized Charcoal. They beſprinkle the Mixture with Water, to hinder the Maſs, compoſed of Matter, which is eaſily inflamed, from heating too much by the repeated Blows of the Peſtils, which break and bruiſe it in the Mortars; and leaſt happening to ſet itſelf at Liberty by a ſudden and too ordinary Inflammation, it ſhould make the Peſtils, Mortars, the Director of the Mill, and the Mill itſelf to fly into the Air. At laſt, the Matter of the Powder, being ſufficiently broken, bruiſed and mixed, is ſifted in ſuch Sort, that paſſing through an Infinity of ſmall Holes it falls in ſmall Grains, to which they have given the Name of Powder, by Reaſon of their Smallneſs and Figure. In one Word, a Mixture of Sulphur, Salt-petre, and Charcoal pounded, and bruiſed in a Mortar, and then paſſed through a Sieve of Hair, and formed into Grains, or divided into ſmall ſpherical Parts, or almoſt ſpherical, is the Compoſition of Gunpowder, of this Powder which produces ſo prodigious Effects.

Eud. Let us examine thoſe Effects by the Help of Philoſophy; and let us endeavour to diſcover their true Cauſe. Things in themſelves the moſt admirable ceaſe to affect us, in Proportion as they become more common. One has too often ſeen the Effects of Powder in the Firelock, to find them ſo marvellous, as they are in themſelves. Powder never fails to aſtoniſh in the Canon, was it only by Reaſon of the dreadful Noiſe, which it cauſes in it, imitating the Lightnings and Thunder, ſo as to make it called the Canon of the Thunder of War. And who can help admiring the Force of Powder, when one ſees with Horror Towers, Forts and Ramparts, rapidly ſhot out above Vortices of Flame and Smoak, which at once iſſue out from a deep Mine? They ſpeak with as much Surprize as Dread of the infernal Machines, eſpecially thoſe of *St. Malo*. They exclaim againſt the artificial Fires. Powder in the Rockets attracts the Eyes of all. Does the Rocket aſcend directly and very high? Does it ſhoot out from its Boſom ſhining Stars? It is certainly a fine one, the fineſt that one has ſeen; it effaces the Stars of Heaven, and the Air reſounds with Applauſe. There needs no more but Eyes, Ears and Senſes, in Order to be affected with ſuch like Effects; but more is neceſſary to diſcover the Cauſe of them, and to unfold their ſecret Springs. The Cannoneer, Miner, and Engineer, ſo familiar with the Powder, do not themſelves ſee thoſe Springs. Perhaps with Eyes a little more philoſophical, we ſhall diſcover them. Let us enquire in the firſt Place after the general Cauſe of the Effects of Gunpowder. After that, we ſhall make Application of the general Cauſe to the Explication of ſome particular Facts.

The Spring of Air contained in every Grain of Powder, and in the Vacuities which the Grains leave between them; the Spring of this Air, I ſay, being extraordinarily bended at firſt, and then dilated by the Inflammation of the Powder, is, I think, the general Cauſe; at leaſt the principal Cauſe of thoſe aſtoniſhing Effects.

My Sentiment is probable at leaſt, if there is plenty of Air in the Grains and Interſtices of the Grains of Powder; if the elaſtic Force of this Air is very great, and ought to be augmented in the firſt Inſtant of Inflammation, and if finally the Springs of the Particles of Air ought to play almoſt at the ſame Time: In this Suppoſition, all the ſmall *Laminæ* of Air are like ſo many bended ſmall Bows, which happening all to be unbended almoſt at one Time, ought to produce conſiderable Effects.

Now, 1. There is Plenty of Air in the Grain, and in the Interſtices of the Grains of Powder. Whilſt in the Mortars of Powder Mills, the Peſtil, as you have ſaid, breaks and divides after a Thouſand different Manners, the Sulphur, Salt-petre, and Charcoal, an infinite Number of ſmall Particles of Air flow and inſinuate themſelves into the Interſtices of this Mixture. Theſe Particles of Air are contained in the Grains; and the Grains, with which the Charge of a Fuſee, Canon, or Mine, *&c.* is compoſed, being almoſt ſpherical, make Angles with one another, which are full of Air.

2. The elaſtic Force of this Air is very great; one may judge of it by the Force which compreſſes it, whether it be in Mortars, or when one charges a Fuſee or Cannon. Thus after having kindled four Grains of Powder in a Glaſs Tube with a burning Mirror, one has obſerved that the Air of the Powder cooled again, poſſeſſed two hundred Times more Space than the four Grains [p].

3. The elaſtic Force of the internal Air ought to increaſe in the firſt Inſtant of Inflammation. Heat, which rarefies free Air, at

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[p] Hiſt. de l'Acad. an. 1696. p. 407.

firſt contracts the Air already condenſed[q], as Experience ſhews us; becauſe the agitated Corpuſcles, which penetrate at firſt into the *Laminæ* or Spires of the free Air, finding no Acceſs into condenſed Air, exert their Force upon the external Surface, and upon a greater Quantity of Air at a Time, becauſe in that Caſe there is more in a determinate Space.

4. Finally, the Springs of the Particles of Air ought to play almoſt all at the ſame Time; for the Force of the Elaſticity quickly prevails, and ſhoots out the Flame rapidly on all Sides. Therefore, *&c.*

What happens, when one puts Fire to the Powder? The Sulphur of the Powder, already filled with ſubtile Matter ſtrongly agitated, takes Fire immediately: The Action of the Fire, by its ſudden Motion, bends again the Springs of the Air already bent. Thoſe Springs being put into a greater Tenſion, and exceſſively bent, are unbent both by the Exceſs of their Force, and by the Help of the Fire, which ſhakes, moves and extricates the ſurrounding Particles of Coal, Sulphur, and Salt-petre. The Springs being bent, throw out on all Sides inflamed Salt-petre. Hence, the Grains of Powder taking Fire ſucceſſively, but with inconceivable Swiftneſs, are all inflamed almoſt at the ſame Time. Thus the Springs of an Infinity of *Laminæ* of Air impriſoned in the

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[q] Ibid. An. 1703. p. 2, 3.

Grains and Angles, play almoſt all in an Inſtant, and ſhoot out on all Sides a Multitude of hard, round and ſolid Particles of Salt-petre, which unite their Forces, rudely ſtrike againſt whatever oppoſes the Direction of their Motion, and make Fuſees, Balls, Bullets, Baſtions, Ramparts, Inhabitants of Towns, and almoſt intire Towns, fly into the Air.

This, I think, is the general Cauſe, at leaſt the principal of the wonderful Effects of Gunpowder. Let us enter into a Detail, and apply this general Cauſe to the explaining of ſome particular Effects. I ſhall ſay nothing why the Powder kindles ſo readily. One preſently conceives that the Sulphur, of which it is compounded, containing very much ſubtile Matter, always ſtrongly agitated, requires no more than a light Augmentation of Motion in Order to be inflamed, and to convey Inflammation into the Charcoal and Salt-petre. Neither ſhall I aſk of you why Powder is kindled upon the Hand without hurting it. 'Tis evident that kindled Powder ought, by Reaſon of its Springs unbent in the Inflammation, to poſſeſs a much larger Space than it did before, and conſequently becoming more light than the Air which ſurrounds it, the Air ought to elevate it by the Exceſs of its Weight, and to hinder its Action upon the Hand: But let us explain ſome Problems which concern the Firelock, Cannon, Rockets, Mines, and infernal Machines.

Whence proceeds the going off of the Ball, and the recoyling of the Fuſee, at the Time of Exploſion?

Ariſt. At the Time of Exploſion, the Spring of the Powder, and eſpecially of the Air contained in the Powder, acts equally on all Sides, before and behind; equally upon the Ball and upon the Breech; after the ſame Manner as the Spring of Air contained in a Foot-Ball driven by two oppoſite Forces, acts equally toward the two oppoſite Parts, whence the contrary Forces come, after the ſame Manner, in a Word, as a bent *Lamina* tends to unbend itſelf from the two oppoſite Sides, with the ſame Violence. The Ball, not being able to reſiſt the Force of the Spring, yields according to the Direction which it receives from it; and this is the Departure of the Ball. The Breech, being no more able to reſiſt the Force of the Spring, yields according to the contrary Direction which it receives from it. And this is the recoiling of the Firelock, which ſometimes throws down the weak Shooter, ſooner than the Prey.

But why does a long Firelock carry farther than a ſhorter one equally charged; provided the Exceſs of Length is not too great?

Eud. In the longer Firelock more Powder is kindled, ſince the Powder, which is ſucceſſively kindled, remains in it longer Time expoſed to the Inflammation. The Inflammation of a greater Quantity of Powder, being longer Time wholly contained in the Chamber of the Firelock, ſtrikes more Blows, and ruder Blows. The Ball being ſtruck more rudely, receives the more Force; and with more Force, it ought to go farther. It reaches to kill a wild Duck, notwithſtanding the Precaution which he had taken to place himſelf in the Middle of a Pond, where he might ſafely have defied the Force of a ſhorter Firelock. If the Exceſs of Length is too great, it diminiſhes the Effect of the Ball; becauſe the Ball is thruſt back inwardly into the Firelock by the Violence of the Air which enters again, or ſtrives to enter after the Inflammation. Hence, *Voſſius* aſſerts that the Length of a Cannon ought not to be more than thirteen Foot[r].

If one ſhoot very cloſe, ſo that the Mouth of the Firelock touch him, who receives the Blow, the Wound is lighter, at leaſt ſo far as we are informed.

Ariſt. In this Situation, the internal Air cannot come out freely from the Firelock; becauſe between the Mouth of the Firelock and the Body which it touches, there is not a Paſſage large enough; and conſequently it oppoſes itſelf the more ſtubbornly to the Direction of the Ball, and diminiſhes its Effort; the Effort being deadened, wounds more lightly. I believe this Reaſon is good enough. Nevertheleſs I frankly own that I would not make the Experiment upon any Body, nor willingly allow any Body to make it upon me.

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[r] De Nili origine; Journ. des Sçav. 1666. p. 387.

Put a little Powder into the Chamber of the Firelock, under the Ball; but over the Ball, put a great deal. Ram down the Firelock, as uſual; the Shot will make a great Noiſe, and little Effect.

Eud. The Noiſe will be great, becauſe all the Powder will take Fire, the Fire being able to paſs from that below to that above, and becauſe all the Powder being inflamed, will cauſe in the Air this impetuous Tremulation, which makes the great Noiſe. The Effect of the Ball will however be very inconſiderable; becauſe the Ball will only be puſhed forward by the ſmall Quantity of Powder, which is below. The greater Part, which is above, will ſerve rather to deaden the Force of the Ball, than to augment it.

So that, if you are diſpoſed to place your ſelf boldly before the Mouth of a Firelock, at ſome Diſtance, you will ſafely receive the Ball into your Hand or Breaſt. You will have the Glory of knowing how to charm Fire-arms, and you will be infallibly invulnerable, without Compact, or Sorcery. A Philoſopher explains ſuch Experiments; but is too wiſe to make 'em.

It would be uſeleſs to demand whence the recoyling of the Cannon and the Departure of the Bullet proceed at the ſame Time.

Ariſt. 'Tis evident that the Cauſe, which makes the Firelock recoil and the Ball to go off, makes alſo the Cannon recoil, and the Bullet to go off. But why does the Bullet advance ſo far, while the Cannon recoils ſo little, or recoils only ſome Paces?

Eud. Becauſe there is as much Force required to make the Cannon with its Carriage recoil ſome Steps, as to convey the Bullet a long Way; ſince, without mentioning the Reſiſtance which proceeds from the Friction that it makes in recoiling, the Cannon with its Carriage recoiling very little, and the Bullet carried a good Way off, are almoſt in the reciprocal *Ratio* of Maſs and Velocity; in Proportion as the Bullet has more Velocity, the Cannon has more Maſs. If the Bullet has an hundred Degrees of Velocity, while the Cannon has only one; the Cannon has an hundred Degrees of Maſs, or thereabouts, while the Bullet has only one; and to carry an hundred Degrees of Maſs one Pace, as much Force is neceſſary, as to carry one Degree of Maſs an hundred Paces; ſo that the Cannon, in recoiling with as much Motion as the Bullet has, ought ſcarcely to advance one Pace, while the Bullet advances an hundred.

But while the Powder is inflamed in the Cannon, if the Touch-hole happen to be ſtopped, the Cannon burſts. Why?

Ariſt. 1. The Powder being inflamed in the Bottom of the Barrel, and in that Caſe not being able to come out in any Sort, nor to relieve itſelf, if I may ſo ſpeak, by the Touch-hole, unites its Efforts againſt the Sides of the Cannon.

2. The external Air, which cannot enter by the ſtopt Touch-hole, cannot act upon the Inflammation in Order to haſten its iſſuing out; it oppoſes it alſo by the Mouth of the Cannon, ſo much the more, becauſe it cannot circulate. Wherefore the kindled Powder makes the greater and more durable Efforts, from the Axis of the Barrel, toward the Circumference of the Cannon. This Exceſs makes it burſt, becauſe it is more eaſie for the Powder to make a Paſſage for itſelf at once through the Sides of the Cannon, than to wait for ſetting itſelf at Liberty by thruſting the Ball, notwithſtanding the Reſiſtance of the Air, all the Way from the Breech to the Mouth of the Cannon. When Bodies have any Difficulties to ſurmount, they always begin with overcoming the leaſt. They have their Manner of acting, their Laws, and their Cuſtoms, which they obſerve inviolably from the Beginning of the World, being much more exact and conſtant in this Point, than the moſt Part of intelli-

gent Beings, which only have more Knowledge in Order to diſcover more Extravagance.

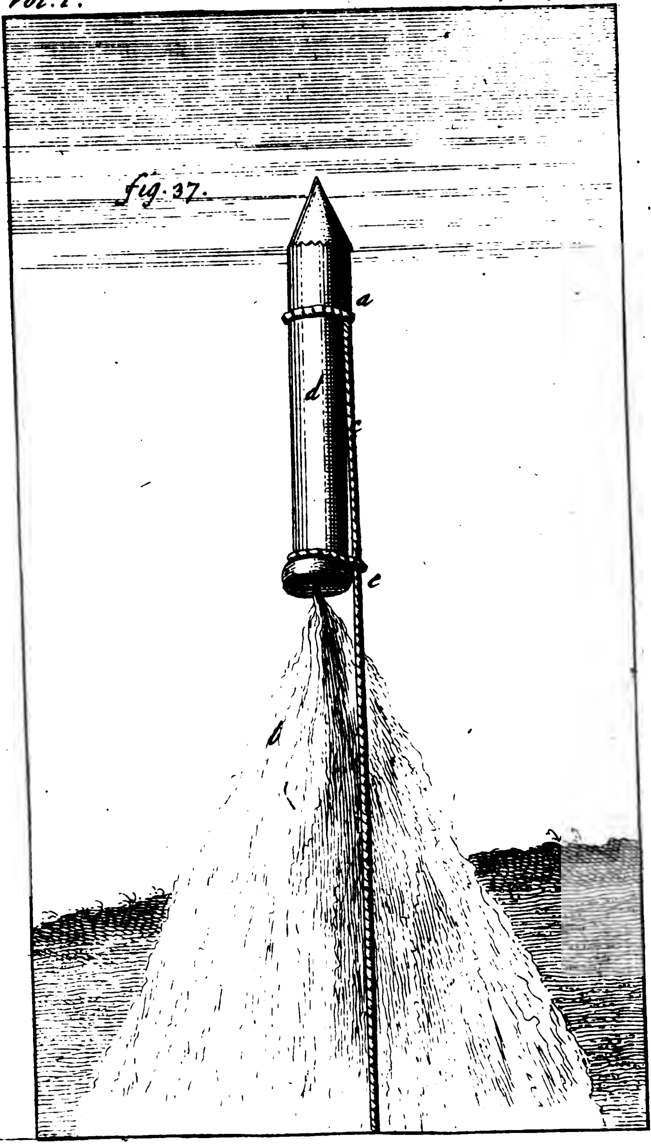
Eud. As for the dreadful Noiſe of the Cannon, it is eaſily comprehended. A great Quantity of kindled Powder is prodigiouſly rarefied in the Inflammation by the Action of an Infinity of Springs, which are unbent almoſt all at a Time. This ſtrange Rarefaction ſtrikes, compreſſes, and drives away a great Maſs of Air; the different Parts of this contracted Maſs, happening to be reſtored with an Acceleration of Motion, are compreſſed again in the Point of Reunion; the Dilatation is repeated. Hence, this Tremulation of the Air which cauſes the terrible Noiſe and Crack, which the Echos of the Mountains and Rocks ſtrive to augment, as it were, through Emulation.

The Rocket, *(a) Fig.* 37. has nothing terrible in it, nor ſurprizes in the leaſt, eſpecially when one knows what makes it aſcend, while the Flame *(b)* iſſues out below.

Ariſt. The Spring of the Powder, or of the Sulphur, Salt-petre, Coal, and Air contained in them, makes the Rocket aſcend, as it makes the Firelock or Cannon recoil. In the Inflammation this Spring makes an univerſal Effort, and acts both toward the Center of the Earth, and toward the Sky. The Effect of the Action toward the Center of the Earth, is to make the Powder or inflamed Matter iſſue

out,

fig. 37.



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out, which finds a Paſſage through the inferior open End. The Effect of the Action of the Spring towards the Sky, is to make the ſuperior Powder or the inflammable Matter to aſcend, and alſo the Tube which contains it, without affording it any Paſſage. After the ſame Manner as the Action of the Powder toward the Breech makes the Firelock or Cannon recoil, becauſe it finds no Paſſage in the Breech; after the ſame Manner the Action of the Powder or inflamed Matter toward the Sky, not finding any Vent in the upper End of the Rocket, makes it recoil and aſcend, and obliges us to carry our Eyes after it toward Heaven.

But for what Uſe ſerves the Rod *(c)*, which they faſten to the Rocket?

Eud. That is to preſerve its perpendicular Direction. Without the Rod the Center of Gravity would ſoon be above the Center of Figure *(d)*; ſince the Powder or inflamed Matter iſſues out every Moment through the inferior Paſſage. In that Caſe the Part which contained the Center of Gravity would outweigh the other; and by Reaſon of the ſmall Inclination of the Rocket, it would make a Semicircle in the Air, overturn itſelf, and deſcend again, ſince the cloſed End would be towards the Earth; the Rocket would move from on high downward, inſtead of moving from below upward. But when the Rod is faſtened to the Rocket, the Center (e) of Gravity of the whole Compound of Rocket and Rod is below the Center of Figure. This Center continually deſcends, ſo far is it from aſcending, in Proportion as the Rocket is elevated. Wherefore the inflammable Matter is always above it; and thus the Rocket preſerves its perpendicular Direction.

Ariſt. But when the Rocket ſeems to be elevated as far as the Clouds, why do we at once ſee ſparkling Stars ariſe?

Eud. Thoſe Stars ſo brillant were nothing leſs than brillant Stars a Moment before they were ſeen. They were ſmall ſolid Balls compoſed of Charcoal, Sulphur, and Salt-petre, but wherein Salt-petre was predominant. Theſe ſmall Balls were contained above the reſt in the Rocket. Being placed above the reſt of the Rocket, they took Fire laſt of all. The Fire threw them out, and ſcattered them on all Sides. The ſmall Particles of Salt-petre, ſolid, round, and infinitely fit for Motion, being rapidly ſhot out from all Sides by the Violence of the kindled Sulphur and unbent Springs, communicate the Motion and Vibrations which they have received to the Matter of the Light. This Matter being more ſubtile and fine than the Air, but diffuſed in the Air from the ſmall inflamed Ball to our Eyes, communicates to our Eyes the Vibrations which it has received; and thoſe Vibrations cauſe in the Soul the Splendor of little Stars, which we think to find in the Air, and at the Sight of which People being ſurprized, and judging rather by the Report of the Eyes than by that of Reaſon, cry out more in an Inſtant, than ever they did upon ſeeing the Heaven adorned with Stars formed by the Hands of the Creator.

From the agreeable Effects of the Rocket we muſt at laſt paſs to the terrible Effects of Mines.

Ariſt. An almoſt infinite Number of Springs being contained in a great Quantity of Powder, happening to be unbent almoſt all at a Time in the Inflammation, and not finding Room enough to extend themſelves in the Stoves, Fougades or ſubterraneous Chambers, agitate the Vaults with a ſtrange Violence, ſhake them, detach them, and make the Half-Moons, Towers and Ramparts fly far off in the Air; and thoſe who defended them are aſtoniſhed to find themſelves ſuddenly whirled into the Air.

Eud. But why has not a Mine its Effect, that is countermined?

Ariſt. Bodies in moving follow the Direction in which they meet with leaſt Oppoſition. The Powder kindled in the Mine that is countermined, finds a free Paſſage, and is in Part exhaled through that. The more of it is exhaled through that, the fewer Efforts it makes againſt the Vault and ſolid Parts of the Mine. Hence the real Efforts are ineffectual, and the Miner being confounded grows pale, and rages to ſee the Enemy at Eaſe over his Mine in Fire.

I think Mines in Fire ought to have very much Relation to infernal Machines, and to produce almoſt the ſame Effects by the ſame Principles.

Eud. The infernal Machines are Machines of War, in which Powder by an extraordinary Inflammation produces horrible Effects, proper for repreſenting to us by the Horror, which it diffuſes; the frightful Image of the Fires of Hell. In Order to our having ſome Idea of them, it is ſufficient to bring to Mind the infernal Machine which was deſigned for burning *St. Malo*, but which was only fatal to the Engineer.

This Machine was made in Form of a Veſſel. It had thirty four Foot in Length, and eighteen in Height, an Hold and three Bridges. There was Sand in the Hold. The firſt Bridge was filled with twenty Thouſand Weight of Powder, with a Foot of Brick-work above it. The ſecond Bridge was adorned with ſix Hundred Firebombs and Carcaſſes, and two Foot of Brick-work above them. The third Bridge over the *Gaillard* was loaded with fifty Barrels with Iron Hoops, full of all Sorts of Fire-Works. The Deck was contrived for conducting Fire to the Primes and Powders. Such almoſt was the infernal Machine[a], which might have cauſed a general Conflagration, and with which *England* broke ſome Glaſs-Windows of *St. Malo*.

For what Uſe ſerves the Sand in the Hold?

Ariſt. The Machine is thereby the more weighty; being more weighty, it draws more Water; drawing more Water, it changes the Direction with greater Difficulty: In Order to change it, a greater Maſs, a greater Bulk of Water muſt be removed. Now with the greater Difficulty the Machine changes Direction, the more certainly the Fire-Works which iſſue out of it reach the Scope.

But for what Uſe ſerves the Brick-work over the Powder?

Eud. You conceive that ſufficiently, *Ariſtus*. The Brick-work retards the Action of the Powder upon the Carcaſſes, Bombs, and Engines. In this Delay, more Powder is kindled; conſequently more Motion is communicated at once; and a greater Force produces a greater Effect. Let us imagine that the Barrels of Powder take Fire, and that the Springs of the Grains of Powder are ſet a going all at a Time. We ſhall ſee the Carcaſſes, red Bullets, and Bombs fill the Air with Fire, fall, break and burn all that comes in their Way. Or rather being content with knowing the Original and Compoſition of Gunpowder, and the phyſical Cauſe of its divers Effects, let us ſpare our Imagination ſo terrible a Spectacle, which Rage alone ſeems to have invented.

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[a] Mem. d'Artillerie de M. de St. Remi, T. I. p. 371. Seconde Edition.

An Effect of Fire more ſalutary, peaceable, and agreeable, is to drive away Cold, and to produce Heat. Will you have us make Heat and Cold the Subject of our next Converſation?

The End of the Firſt Volume.